

JOURNAL OF AGRICULTURAL RESEARCH

VOLUME XIX

APRIL 1—SEPTEMBER 15, 1920

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE
WITH THE COOPERATION OF THE ASSOCIATION
OF LAND-GRANT COLLEGES

WASHINGTON, D. C.

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ERRATA AND AUTHORS' EMENDATIONS

Page 97, line 26, "were" should read "would be."

Page 110, Table I, column 1, line 13, "24" should read "23."

Page 136, line 2, "*Pseudococcus bomensis*" should read "*Pseudococcus bominis*."

Page 202, following line 16, add "*C. trifoliata* seedlings, however, on testing are readily susceptible to the disease."

Page 232, Table XVI, footnote, " $r = -0.452 \pm 0.068$ " should read " $r = -0.166 \pm 0.063$."

Page 236, line 1, "The spores, both conidia and ascospores, behaved alike in germination" should read "The conidia from both conidia and ascospores behaved alike in germination."

Page 242, line 22, " $\text{Al}_2(\text{SO}_4)_3 \cdot 0.18 \text{H}_2\text{O}$ " should read " $\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$ " and " $\text{FeSO}_4 \cdot 0.7 \text{H}_2\text{O}$ " should read " $\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$." The same correction should be made in Tables III, IV, V, and VII.

Page 278, Plate 47 and legend. "Internal hilar sorus shown at x" should be omitted. The marking x is incorrectly placed on the plate. There are two internal hilar sori shown in the lower right-hand portion of the plate.

Page 362, legend for Plate 59, line 10, "Infected leaves from twigs" should read "Infected leaves and twigs."

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JOURNAL OF AGRICULTURAL RESEARCH

VOL. XIX

WASHINGTON, D. C., APRIL 1, 1920

NO. 1

A TEOSINTE-MAIZE HYBRID

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INTRODUCTION

The only plant which has been considered as an ancestor of our cultivated varieties of maize is teosinte (*Euchlaena mexicana* Schrad.). Although placed in a different genus and separated by pronounced morphological differences, teosinte hybridizes freely with maize. In Mexico, where teosinte is native, both teosinte and maize frequently show contamination. Dilute maize hybrids are of such general occurrence in teosinte that it is difficult to decide whether the various forms of teosinte have all descended from one or more wild species.

In attempting to determine more definitely the relation of teosinte to the origin of maize, it is important to know something of the mode of inheritance of the characters which separate the two genera. The following paper is a study of the behavior of a number of the more sharply contrasted characters in the second generation of a hybrid between Florida teosinte and a diminutive variety of maize known as Tom Thumb pop corn. This variety of maize was chosen on account of its very short season and the large number of characters in which it contrasts sharply with teosinte.

The name Florida teosinte is applied to the variety cultivated for forage in the southern part of the United States. This variety shows less evidence of contamination with maize than any other form that has come under our observation, and for this reason it was chosen for these experiments. It is not known how this plant reached Florida. What appears to be the same variety has been obtained from Tampico and Monterey, Mexico, but whether it is native in Mexico has not yet been determined. Seed of the Florida variety has found its way to many tropical countries, and it may have been introduced into eastern Mexico, either directly or indirectly, from Florida. Teosinte is wild in western Mexico; but none of the forms known from that side of the country can with any assurance be referred to the same variety, or even to the same species as the Florida plant.

The restriction of seed production to southern Florida is probably the chief reason why the use of teosinte is not more general, since it is an excellent forage plant. Where comparative tests have been made, it usually produces a larger tonnage of forage than any other plant.

It has been pointed out by Gernert¹ that teosinte is resistant to the attacks of plant lice, an immunity that it would be desirable to transfer to maize. Teosinte also appears to be more resistant to corn smut than any of the varieties of maize with which we are familiar. Stok² reports that in Java teosinte is immune to the chlorosis disease of corn.

Hybrids of maize and teosinte have been grown before, but nothing of commercial importance has thus far been produced. It would seem, however, that if certain combinations of characters could be effected and maintained, the resulting forms would find a place in agriculture.

One of the objects of the experiment was to determine to what extent the characteristics of the parents would be disassociated in the hybrids. Would the much-branched habit of teosinte continue to be associated with a teosinte-like inflorescence, or would profusely branched plants appear bearing maize-like ears? Would the early maturing plants all be maize-like or would there be early plants having the desirable forage characteristics of teosinte?

To proceed with any assurance in securing the desired combinations, it would be of advantage to know to what extent the characters can be separated and with what degree of freedom desirable characters from the different parents can be combined. If, as has been stated,³ hybrids of maize and teosinte eventually revert to either one or the other parent, it would be futile to attempt to secure desirable combinations.

From the standpoint of genetics, the cross is of especial interest, since perhaps nowhere else, with either plants or animals, has it been possible to secure fertile hybrids between two forms separated by such profound structural differences.

FIRST GENERATION OF TEOSINTE-MAIZE HYBRID

Several unsuccessful attempts were made to hybridize the Tom Thumb pop corn and the Florida teosinte in the field, the great disparity in their seasons making it difficult to bring them into flower at the same time. These efforts were continued in the greenhouse, and the hybrids were finally secured in the early spring of 1914.

Because of the peculiar effect of greenhouse conditions, the parental teosinte plants were greatly reduced in size and presented an unusual

¹ GERNERT, W. B. APHIS IMMUNITY OF TEOSINTE-CORN HYBRIDS. *In Science*, n. s. v. 46, no. 1190, p. 390-392. 1917.

² STOK, J. E. VAN DER. BESPREKING DER RESULTATEN VERKREGEN MET DE KRUISING TUSSEN ZEA MAIS L. (MAIS, DJAGOENG) (=REANA LUXURIANS DUR.=TEOSINTE). EN EUCHLAENA MEXICANA SCHRAD. *In Teysmanna*, jaarg. 21, afl. 1, p. 47-59, 1 pl. 1910. Abstract in English in *Amer. Nat.*, v. 47, no. 560, p. 511-512. 1913.

³ HARSHBARGER, J. W. FERTILE CROSSES OF TEOSINTE AND MAIZE. *In Gard. and Forest*, v. 9, no. 462, p. 522-523. 1896. Quotes a letter from Dr. Dugés.

appearance. The plants consisted of single culms not in excess of 50 cm. in height with no suckers and with only from 8 to 11 total nodes. The flowering habits also were affected, the simple culms each terminating in a single spike which produced very little pollen, while the pistillate spikes were borne directly in the axils of the upper two or three sheaths. Accompanying the reduction in size and the alteration in appearance was a corresponding reduction in the time elapsing between germination and flowering. Normal plants grown in Florida flower in about 200 days after germination, while the plants raised in the greenhouse flowered in about 70 days.

The Tom Thumb plants, from seed sown a week or two later, were more nearly normal. Although somewhat reduced in height, the plants produced from 8 to 11 nodes, which is the usual range under field conditions. The terminal inflorescences were entirely staminate, pistillate flowers being produced only in the normal position.

Because of lack of teosinte pollen, all the hybrids were made by using teosinte plants as the female parents. Since the greatest number of seeds in a spike never exceeded 6, the quantity of hybrid seed was small. Three teosinte plants were used as female parents, and a total of 11 hybrid seeds was secured. All these seeds plainly showed the effect of hybridization, being increased in size until they protruded from the hardened glumes.

Nine of the 11 seeds were planted at Lanham in the spring of 1914 and 5 plants reached maturity, though the production of viable seed was prevented by early frosts. Four of the 5 plants were strikingly similar in appearance, and the structure of the inflorescence was alike in all. The fifth plant, though like the preceding 4 in floral characteristics, was greatly reduced in size; in fact, it was little if any taller than normal Tom Thumb but had numerous suckers.

The four normal F_1 plants were about 18 dm. high with 6 or 7 suckers arising from nodes below the ground. These suckers usually equaled the main stalks in height. In appearance they were replicas of the main culms, though in time of flowering they behaved like those of maize, being several days later. The branching of the main stalk was not continuous, 1 or 2 nodes usually failing to develop branches. These branchless nodes were about the eighth or ninth produced. The total number of nodes on the main culm ranged from 17 to 21. The uppermost branch on three of the plants was in the third node from the top, while the fourth plant was similar to pure teosinte in bearing the uppermost branch at the second node.

The terminal panicles resembled those of maize in that they all had 8-rowed central spikes instead of terminating in a 4-rowed branch as in teosinte; but in three of the four plants this 8-rowed spike drooped as in teosinte, while in maize the central spikes are erect. The pistillate spikes of the hybrid were all 4-rowed, with the spikelets paired and the spikes

decidedly flattened. The plants were much more proterandrous than even normal maize, and the first silks appeared from the basal or prophyllary node of the uppermost branch. About 95 days elapsed from the date of germination before the first pollen was shed, and the first silks appeared from 10 to 21 days later. The season proved to be too short to mature the fruit properly, and no viable seeds were obtained. A photograph of one of the F_1 plants is shown in Plate 6, C, and the pistillate inflorescence of the same plant in Plate 7.

The two seeds remaining from the original cross were planted at Chula Vista, Calif., in 1915, but only one plant was brought to maturity. This plant produced viable seed and became the parent of the second generation discussed in the present paper. Although grown in a climate decidedly different from that at Lanham, Md., the F_1 plant at Chula Vista was strikingly similar in every respect to its sister plants grown the preceding year. It also was proterandrous, though requiring 102 days from germination to the shedding of pollen. The uppermost branch was in the second node from the top, and the plant produced many suckers arising from nodes below the ground. The terminal panicle had an 8-rowed central spike, and the female spikes were all 4-rowed, as in the Lanham plants.

Since the F_1 plants were comparatively uniform, it was not until the great diversity of the second generation became apparent that the characters were formulated. Consequently many of the characters subsequently used were not recorded for the F_1 plants, and no direct comparisons could be made. In any case, the very small number of F_1 plants precluded statistical analysis.

SECOND GENERATION OF TEOSINTE-MAIZE HYBRID

The second generation, consisting of 127 plants, was grown at Chula Vista in the season of 1916. The hills were spaced 4 feet by 3 feet, and only one seed was planted in a hill. This generous spacing, together with the fact that the germination was low, removed all effects of crowding and allowed the plants to develop naturally, an important feature with plants exhibiting such a wide range of size, habits of growth, and season of maturity.

The impression gained from the general appearance of the F_2 plants was that the great majority were of one type, with the remaining plants falling into other fairly well-defined classes. This impression was dispelled as the plants were carefully examined and the measurements of individual characters recorded. The general impression of uniformity was doubtless due to the fact that the branching habit of a plant is its most conspicuous feature. (See Pl. 1.) The measurements showed, in fact, that the number of suckers was among the least variable of the characters measured, 65 per cent of the plants having between 7 and 15 suckers.

METHODS OF MEASUREMENT

The field measurements¹ of the characters, including dates of flowering and size and number of the several organs, were transferred to punched cards, each card representing an individual plant. Practically all the calculations were made by the use of electric sorting and tabulating machines. The distribution and means were obtained by sorting with respect to each character, using the tabulator to count the cards in each class.

In calculating the standard deviation the departures were taken from zero, as recommended by Harris.²

The formula used was $\sigma = \sqrt{\frac{\sum D^2 f}{N} - M^2}$, where σ = standard deviation;

D = departure—in this instance, the class; f = frequency; N = total number; and M = mean. $\sum D^2 f$ was found by multiplying on a calculating machine the summed values for each class (as found by the tabulating machine) by the class and summing the products.

The formula for calculating correlation coefficients proposed by Jennings³ was found to be admirably adapted to the use of tabulating machines.

The formula is

$$r = \frac{\sum XY \cdot N - \sum X \cdot \sum Y}{\sqrt{(\sum X^2 \cdot N - (\sum X)^2) \cdot (\sum Y^2 \cdot N - (\sum Y)^2)}}$$

in which X and Y = the values of the measurements and N = the number of individuals.

In applying this formula the following procedure is recommended by Jennings. Find the values: $\sum X$, $\sum X^2$, $\sum Y$, $\sum Y^2$, and $\sum XY$; next find the values of a , b , and c as follows:

$$a = \sum XY \cdot N - \sum X \cdot \sum Y$$

$$b = \sum X^2 \cdot N - (\sum X)^2$$

$$c = \sum Y^2 \cdot N - (\sum Y)^2$$

Then

$$R_x = \frac{a}{b}$$

$$R_y = \frac{a}{c}$$

and finally $r = \sqrt{R_x \cdot R_y}$.

Since the use of mechanical tabulating machines in the calculation of correlations seems not to have been described, it may not be out of place to explain the procedure followed.

¹ It was necessary to go over the field at intervals of two or three days throughout the growing season to record flowering dates and the position of first silk and to insure an accurate count of the total number of leaves. This work, together with the planting and care of the experiment, was done by Mr. C. G. Marshall.

² HARRIS, J. ARTHUR. THE ARITHMETIC OF THE PRODUCT MOMENT METHOD OF CALCULATING THE COEFFICIENT OF CORRELATION. *In Amer. Nat.*, v. 44, no. 527, p. 693-699. 1910.

³ JENNINGS, H. S. HEREDITY, VARIATION, AND THE RESULTS OF SELECTION IN THE UNIPARENTAL REPRODUCTION OF *DIPLUGIA CORONA*. *In Genetics*, v. 1, no. 5, p. 407-534. 19 figs. 1916.

The first step in calculating product moment correlations was to reject all cards which did not have values recorded for all the characters. This left a population of 88. The cards were then sorted into the classes of the first character (X of the formula), and the classes were separated by stop cards. While the cards were in this order the tabulator gave the summed values for each of the characters for each class of the first character ($\Sigma_x X$ and $\Sigma_x Y$), the number of individuals in each class, and the total value for each of the characters. Each of the entries in the table thus formed ($\Sigma_x X$ and $\Sigma_x Y$) was then multiplied by the class value, and the products were summed on a calculator, giving ΣX^2 and ΣXY .

These summations when multiplied by the number gave $\Sigma X^2 \cdot N$ for the first character and $\Sigma XY \cdot N$ for the remaining characters in the formula for all correlations with the first character. The totals for each character multiplied by the total of the first character gave $(\Sigma X)^2$ for the first character and $\Sigma X \cdot \Sigma Y$ for the remaining characters.

The cards were then sorted for the second character, and the same procedure was followed. In each operation the totals should check, and since each character entered as both X and Y , no additional checking is necessary, each correlation being in effect calculated twice with each operation independently checked. The actual regression lines were readily plotted by dividing the values ΣYX by the number of individuals in the respective classes.

The number of characters for which all correlations can be calculated is limited, of course, by the number that can be recorded on a card. The largest card at our disposal had 45 columns, which would accommodate but 26 characters; and since we wished to consider 33 characters, a second card was used on which the more important characters were repeated, with the addition of the characters not recorded on the first card.

The distributions in the alicole group were bimodal to an extent that seemed to preclude the use of the product-moment method. Correlations within this group were, therefore, calculated by Yule's method for the coefficient of association. Biserial correlations were used to determine the relation between alicole characters and characters outside this group.

Probable errors are not given in the table, since all correlations were calculated from the same population of 88 individuals. In the discussion, correlations of less than 0.25, which is 3.5 times the error, are considered insignificant.

In discussions of genetic correlations it is necessary to distinguish between the instances where two characters derived from the same parent tend to be inherited together and those where one of the characters has entered the hybrid from one parent and the correlated character has been derived from the other parent.

The terms "coherence" and "disherence" will here be used to designate the direction of the correlations with respect to the parental combinations.

The terms "linkage" or "coupling," which are in more general use, might be used in place of coherence; but both these terms imply that the relation is between Mendelian or alternative characters, while most of the characters under discussion show quantitative instead of alternative differences. Furthermore, there appears to be no term in general use that can be applied to the cases where the correlation is the opposite of a linkage or coupling. The use of the word "repulsion" would seriously confuse the issue, since that term implies the disassociation of dominant characters without regard to whether they have entered the hybrid from the same or different parents. In using "coherence" instead of "linkage" there is no intention to imply that the ultimate determinants of the characters are not inherited in Mendelian fashion; but since no attempt toward factorial analysis is made, it seems better to use a more general term.

DESCRIPTION OF CHARACTERS

Thirty-three characters were recorded and their correlations considered. Many of these characters fall into groups the members of which would seem to be mutually related, either physically or physiologically. Eight such groups are recognized, comprising in all 26 characters. Among the 7 remaining characters considered as independent, physiological relations, if they exist, are more obscure. The grouping of the characters is shown below, with the abbreviated designations of the characters which will be used throughout the paper.

HEIGHT GROUP (P. 11-16)

HEIGHT.—Height of the main culm in decimeters.

TOTAL LEAVES.—Total number of leaves or nodes produced on the main culm.

HEIGHT OF SUCKER.—Height of the tallest sucker or tiller in decimeters.

SUCKER INDEX.—Height of the tallest sucker, expressed as a percentage of the height of the main culm.

CIRCUMFERENCE INDEX.—Circumference of the thickest internode in millimeters, expressed as a percentage of the height of the main culm measured in centimeters.

NODES WITHOUT BRANCHES.—Number of nodes between the uppermost sucker, or the surface of the ground, and the lowest developed branch.

NODES ABOVE GROUP (P. 16-19)

NODES ABOVE.—Number of nodes on the main culm above the ear or uppermost branch.

NODES ABOVE ON THIRD.—Number of nodes above the uppermost secondary branch of the third branch from the top.

NODES ON THIRD.—Number of nodes on the third primary branch from the top.

TASSEL GROUP (P. 19-21)

PRIMARY BRANCHES.—Number of primary branches in the terminal inflorescence of the main culm.

SECONDARY BRANCHES.—Number of secondary branches in the terminal inflorescence of the main culm.

SECONDARY INDEX.—Number of secondary branches, expressed as a percentage of the primary and secondary branches combined.

TASSEL BRANCHES ON THIRD.—Number of branches in the terminal inflorescence of the third branch from the top.

MALE BRANCH GROUP (P. 21-22)

MALE BRANCH INDEX.—Number of primary branches terminating in a staminate inflorescence, expressed as a percentage of the total leaves.

MALE SECONDARIES.—Number of secondary branches terminating in a staminate inflorescence on the third branch from the top.

ALICOLE GROUP (P. 22-25)

DOUBLE MALE ALICOLES.—Number of alicoles or alveoli with two staminate spikelets in the best-developed spike of the pistillate inflorescence, expressed as a percentage of the total number of alicoles in the spike.

MIXED ALICOLES.—Number of alicoles with one staminate and one pistillate spikelet in the best-developed spike, expressed as a percentage of the total number of alicoles in the spike.

SINGLE FEMALE ALICOLES.—Number of alicoles with a single pistillate spikelet in the best-developed spike, expressed as a percentage of the total number of alicoles in the spike.

DOUBLE FEMALE ALICOLES.—Number of alicoles with two pistillate spikelets in the best-developed spike, expressed as a percentage of the total number of alicoles in the spike.

ALICOLE INDEX.—Number of alicoles with a single pistillate spikelet, expressed as a percentage of the sum of single and double female alicoles in the spike.

NODES SILKING GROUP (P. 25-26)

NODES SILKING ON THIRD.—Number of nodes producing silks on third branch from top.

NODES SILKING INDEX.—Number of nodes producing silks on third branch, expressed as a percentage of the number of nodes on the third branch.

PROPHYLLARY GROUP (P. 26-27)

PROPHYLLARY SPIKES.—Number of pistillate spikes in the axil of the prophyllum of the third branch.

LENGTH OF PROPHYLLARY.—Length in centimeters of the prophyllary branch of the third branch from the top.

NUMBER OF ROWS GROUP (P. 27-28)

ROWS IN CENTRAL SPIKE.—Number of rows of spikelets in the central spike of the terminal inflorescence of the main culm.

ROWS OF ALICOLES.—Number of rows of alicoles in the best-developed pistillate spike of the third branch from the top.

INDEPENDENT CHARACTERS (P. 23-33)

POSITION OF BEST SPIKE.—Position on the third branch of the node bearing the best-developed spike. The nodes were numbered from the base of the branch, the branch in the axil of the prophyllum being recorded as zero.

NUMBER OF ALICOLES.—Number of alicoles in the best-developed spike of the third branch from the top.

NUMBER OF SUCKERS.—Number of branches on the main culm or on primary branches that originated below or near the surface of the ground.

BRANCH SILKING FIRST.—Number of branches on the main culm above the branch on which silk appeared earliest.

DAYS TO POLLEN.—Number of days from planting to the first production of pollen.

POLLEN TO SILK.—Number of days from the first production of pollen to the first emergence of silks.

LENGTH OF INTERNODE ON THIRD.—Length of the third branch from the top divided by the number of internodes on the same branch.

The reasons for the grouping of the characters are in most instances obvious. A discussion of the less obvious relationships will be found under the descriptions of the various characters.

All measurements of characters pertaining to the pistillate inflorescence were taken on the third branch from the top of the plant. Some limitation of this kind was necessary to simplify the comparisons, and this branch was chosen as representing the region of maximum development of seed. Reference to Tables I and II shows that in pure teosinte this is the branch with the largest spikes and the largest number of seeds per node.

TABLE I.—Number of spikes at each node of the various branches of a plant of Florida *teosinte*

[illegible]

TABLE II.—Number of seeds at each node of the various branches of a plant of *Florida teosinte*

[illegible]

A knowledge of the behavior of the individual characters in the second generation can best be obtained by a study of the distribution diagrams, figures 1 to 33.

To facilitate the study of the relation of the characters to one another in inheritance, the table of correlations, Table III, is provided. Anything approaching a complete analysis of the data is, of course, out of the question; but the correlation coefficients and the statistical constants given in Tables IV and V afford a means for testing the validity of any assumed relationship. In the discussion of the characters an attempt will be made to indicate the more striking correlations.

TABLE IV.—Distribution of individuals in F_2 of teosinte-maize hybrid with respect to various characters

Units of measurement.	Height (fig. 2). ^a	Total leaves (fig. 2). ^a	Height of sucker (fig. 3). ^a	Nodes without branches (fig. 6). ^a	Nodes above (fig. 7). ^a	Nodes above on third (fig. 8). ^a	Nodes on third (fig. 9). ^a	Primary branches (fig. 10). ^a	Secondary branches (fig. 11). ^a	Tassel branches on third (fig. 12). ^a	Male secondaries (fig. 13). ^a	Nodes stilling third (fig. 21). ^a
0.				79	1				2	7	56	1
1.				4	85				1	10	10	
2.				9	34	67				9	10	
3.				12	3	10			6	11	13	3
4.				5	2	3			11	11	6	27
5.				3			22	1	4	7	12	26
6.			1	2		1	29		8	9	10	25
7.			1	2			24		9	8	4	21
8.	5		2	2			20		10	10	1	9
9.	5	1	1	1			7	4	8	1		3
10.	6	2					12	4	7			1
11.	5	4					3		9	13		
12.	25		12				1	5	1	5		
13.	4	1	7				11	7	1			
14.	21	1	11				1	9		2		
15.	9	1	8				10	2		3		
16.	11	4	21				11	4		2		
17.		9	11	12			12	2				
18.		8	14				14	3		1		
19.		5	10	7			9	2				
20.		3	7	10				5	4			
21.		1	19	5			11					
22.		4	3	4				5	4			
23.		1	11					5	1			
24.			6	1				3	2			
25.			8	1				1	1			
26.			5						2			
27.			1						1			
28.			7					1	2			
29.			3					1	1			
30.			6									
31.			3									
32.			1									
33.			5						3			
34.									1			
35.									1			
36.												
37.									1			
38.			1									
39.									1			
40.												
41.												
42.									1			
43.												
44.												
45.									1			
46.												
47.												
48.												
49.												
50.												
51.												
52.												
53.												
Number.....	123	122	123	120	125	122	123	125	125	112	122	121
Mean.....	12.1	22.7	16.2	1.28	1.36	1.78	7.0	16.8	10.9	6.13	2.04	5.52
Standard deviation.....	4.0	5.1	3.47	2.21	.62	.81	1.92	4.1	11.8	4.07	2.39	1.67

^a Figures indicate number of plants exhibiting each character to the extent shown in the first column. For discussion of units of measurement see p. 7-8.

Characters considered.	Height.	Total leaves.	Height of sucker.	Sucker index.	Circumference index.	Nodes without branches.	Nodes above.
Height.....	.....	0.69	0.71	D-0.41	-0.62	D 0.72	-0.20
Total leaves.....	0.69	.....	.32	D- .48	- .31	D .44	- .20
Height of sucker.....	.71	.32	.....	.30	.....	D .04	- .14
Sucker index.....	D- .41	D- .48	.30	.....	D .51	- .37	D .11
Circumference index.....	- .62	- .31	.....	D .51	.....	.....	.08
Nodes without branches.....	D .72	D .44	D .04	- .37	.....	.....	.11
Nodes above.....	- .20	- .20	- .14	D .11	.08	.11	.....
Nodes above on third.....	- .17	.21	- .06	D .17	.14	D- .03	.57
Nodes on third.....	- .18	.16	D .04	D .31	.....	D- .22	.32
Primary branches.....	.45	.45	.23	D- .32	.00	D .18	- .03
Secondary branches.....	.64	.66	.35	D- .36	.....	D .29	- .34
Secondary index.....	.47	.52	.....	D- .12	- .11	.....	- .30
Tassel branches on third.....	.19	.18	.10	D- .15	.....	D .10	- .09
Male branch index.....	D- .11	D- .07	D- .10	D- .03	.....	- .49	- .31
Male secondaries.....	D- .28	D- .41	.03	.42	D .43	- .30	D .09
Double male alicoles.....	.00	.00	.....	.12	.00	.....	.00
Mixed alicoles.....	.00	.00	.....	.29	.00	.....	.00
Single female alicoles.....	.07	.14	.....	.00	D .20	.....	- .20
Double female alicoles.....	D .07	- .14	.....	- .07	D- .03	.....	.18
Alicole index.....	D- .04	.14	D- .03	.02	.....	- .09	- .22
Nodes silking on third.....	.01	.05	.06	.06	.00	- .03	- .04
Nodes silking index.....	D- .46	.12	D- .02	D- .23	.....	- .07	- .17
Prophyllary spikes.....	.07	.01	D- .01	D- .12	.00	- .17	- .13
Length of prophyllary.....	.16	D- .04	.20	.01	D .02	- .17	- .09
Rows in central spike.....	D .05	- .14	D .06	D- .01	D- .03	.02	.20
Position of best spike.....	- .20	- .18	D .03	D .31	.21	D- .15	.10
Number of alicoles.....	D .07	- .18	D .17	D .09	.12	D- .12	.20
Number of suckers.....	.05	D- .10	.21	.17	- .19	- .31	- .15
Branch silking first.....	.02	.33	.02	D- .36	.....	D .04	- .30
Days of pollen.....	.47	.79	.14	D- .42	- .17	D .36	- .23
Pollen to silk.....	D .11	D .02	.....	D .18	.31	.....	D- .06
Length of internode on third.....	D- .33	D- .66	.02	.48	.....	- .29	D .04

TABLE IV.—*Distribution of individuals in F₂ of teosinte-maize hybrid with respect to various characters—Continued*

Units of measurement.	Prophyllary spikes (fig. 23) ^a	Length of pro- phyllary (fig. 24) ^a	Rows in central spike (fig. 25) ^a	Rows of ali- coles (fig. 26) ^a	Position of best spike (fig. 27) ^a	Number of ali- coles (fig. 28) ^a	Number of suck- ers (fig. 29) ^a	Branch, sili- ling first (fig. 30) ^a	Days to pollen (fig. 31) ^{a, b}	Pollen to silk (fig. 32) ^a	Length of inter- node on third (fig. 33) ^a
0.....	23	13			22		3		3	1	
1.....	23				23			43	15	2	
2.....	12			111	18		1	43	27	1	2
3.....	12			29	10		2	11	25		1
4.....	10		23	1	17		8	6	15	1	6
5.....	11	3	14		6		2	3	13	1	4
6.....	8		19	1	5		3		11	5	5
7.....	5		5		3	1	11		10	4	5
8.....	1	3	62		1	1	8		3	4	14
9.....	2	7			2	3	10		3	5	5
10.....	3	9	2			1	8		3	8	15
11.....	1					1	10			5	8
12.....		15				5	9			3	17
13.....		15				9	11			5	9
14.....	1	8				9	9			1	6
15.....		9				7	7			3	6
16.....		7				10	2			8	3
17.....		4				6	1			7	5
18.....		4				16	5			6	3
19.....		2				14	2			6	
20.....		2				8	5			8	4
21.....		1				4	2			2	
22.....		2				2	3			1	1
23.....		3				5	1			6	
24.....		2								3	
25.....		1				2				4	
26.....						4				4	
27.....		1					1			4	
28.....						1				3	
29.....						1				1	
30.....						3				1	
31.....											
32.....		2					1			1	
33.....										1	
34.....						2				1	
35.....										3	
36.....										1	
37.....		1								2	
38.....											
39.....										1	
40.....		1									
41.....						2					
42.....		1									
43.....										1	
44.....											
45.....										1	
46.....											
52.....										1	
53.....										1	
Number.....	114	121	125	123	120	123	127	105	125	122	119
Mean.....	19	13.4	6.62	2.13	2.47	17.9	11.7	1.89	111.9	18.2	10.9
Standard deviation.....	3.04	7.69	1.87	.38	2.14	6.17	3.50	.44	21.5	9.7	4.19

^a Figures indicate number of plants exhibiting each character to the extent shown in the first column. For discussion of units of measurement see p. 7-8.

^b First date recorded 71 days after planting and subsequently at 10-day periods.

DISCUSSION OF CHARACTERS AND THEIR CORRELATIONS

HEIGHT GROUP

HEIGHT

Confining the measurement of height to the main stalk does not always give a fair idea of the size of the plant, since there were many individuals in which the suckers greatly exceeded the main stalk. (See distribution of sucker index, Table V.)

TABLE V.—Distribution of individuals in F_2 of teosinte-maize hybrid with respect to characters recorded as indices

Units of measurement.	Double male alicoles (fig. 16). ^a	Mixed alicoles (fig. 17). ^a	Single female alicoles (fig. 18). ^a	Double female alicoles (fig. 19). ^a	Alicole index (fig. 20). ^a	Units of measurement.	Sucker index (fig. 4). ^a	Units of measurement.	Circumference index (fig. 5). ^a	Units of measurement.	Secondary index (fig. 12). ^a	Units of measurement.	Male branch index (fig. 14). ^a	Nodes silking index (fig. 22). ^a
<i>Per ct.</i>						<i>Per ct.</i>		<i>Per ct.</i>		<i>Per ct.</i>		<i>Per ct.</i>		
0-4	105	110	34	18	35	41-50	1	24	1	0	2	0-9	1	1
5-14	2	6	27	4	25	51-60	2	25	1	1-10	1	10-19	2	.....
15-24	3	1	13	6	12	61-70	1	26	1	11-20	13	20-29	20	.....
25-34	0	5	5	4	5	71-80	1	27	.....	21-30	12	30-39	23	.....
35-44	5	3	5	8	5	81-90	11	28	.....	31-40	17	40-49	48	.....
45-54	4	.....	.....	7	5	91-100	20	29	1	41-50	12	50-59	15	.....
55-64	.....	.....	.....	.....	.....	101-110	30	30	.....	51-60	12	60-69	5	.....
65-74	.....	.....	.....	6	4	111-120	21	31	2	61-70	12	70-79	4	.....
75-84	.....	.....	.....	14	4	121-130	19	32	1	71-80	9	80-89	.....	.....
85-94	.....	.....	.....	5	3	131-140	7	33	4	81-90	8	90-99	.....	.....
95-100	.....	.....	12	24	19	141-150	2	34	1	91-100	7	100	.....	35
.....	.....	.....	.....	.....	.....	151-160	1	35	3	101-110	7	.....	.....	.....
.....	.....	.....	.....	.....	.....	161-170	.....	36	3	111-120	4	.....	.....	.....
.....	.....	.....	.....	.....	.....	171-180	1	37	2	121-130	3	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	38	5	131-140	1	.....	.....	.....
.....	.....	.....	.....	.....	.....	221-230	1	39	4	141-150	2	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	40	8	151-160	2	.....	.....	.....
.....	.....	.....	.....	.....	.....	451-460	1	41	7	161-170	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	42	5	171-180	1	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	43	5	181-190	3	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	44	6	191-200	1	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	45	5	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	46	4	321-330	1	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	47	4	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	48	5	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	49	3	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	50	4	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	51	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	52	1	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	53	2	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	54	4	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	55	3	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	56	1	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	57	4	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	58	2	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	61	1	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	62	1	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	63	2	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	66	1	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	78	1	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	83	1	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	91	1	.....	.....	.....	.....	.....
No.	123	123	123	123	123	.....	119	.....	110	.....	124	.....	118	121
M.	4.55	2.36	21.4	61.0	34.0	.....	121.5	.....	45.2	.....	70.0	.....	41.5	80.6
σ	11.0	7.95	46.5	68.0	41.3	.....	37.7	.....	12.4	.....	49.0	.....	8.8	18.8

^a Figures give number of plants exhibiting each character to the extent shown in first column in this section of the table.

The average height of Tom Thumb maize plants at Chula Vista was 6 dcm. and that of Florida teosinte 23 dcm. The F_1 plants averaged 17 dcm. The mean of the F_2 plants was 14. The range was from 2 to 23 dcm. The distribution (fig. 1) was as nearly normal as could be expected from the number of individuals involved. There is, furthermore, no indication of skewness, the mode and the mean practically coinciding.

Although the parental varieties differ greatly in height, the parental species overlap. Indeed the taller varieties of maize probably exceed the tallest teosinte in height.

Height is positively correlated with all of the four tassel measurements, and the correlations are significantly higher than was found in a progeny

of Tom Thumb where two of these characters were recorded. Thus there is evidence of coherence between height and the character of the tassel.

Disherence with male secondaries is indicated by a correlation of -0.28 ± 0.07 . The negative correlation of -0.46 ± 0.06 with nodes silking index would also seem a clear example of disherence.

The correlation of 0.47 with days to pollen indicates coherence of this character with height. In both parent populations this correlation was negative, but under most circumstances the late plants of a maize variety are taller than the early plants.

The negative correlation of -0.33 with length of internode on third is in the direction of a disherence, though this is probably associated with the negative correlation between height and sucker index, which is to some extent physical. Anything which tended to interfere with the growth of the main culm would doubtless stimulate the development of all the branches.

TOTAL LEAVES

The total number of leaves on the main culm in Tom Thumb is usually 11, in Florida teosinte about 37. The mean in the F_2 hybrid plants was 23, with a range from 9 to 38. The distribution (fig. 2) is normal, and the variability

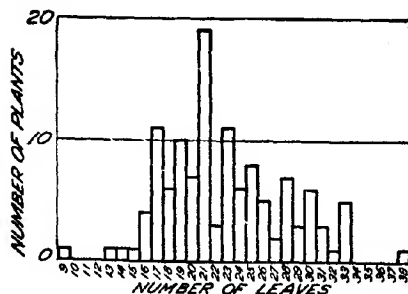


FIG. 2.—Total leaves: frequency distribution of plants in F_2 . Class value, one leaf.

as measured by the coefficient of variation is the lowest recorded for any character.

The larger varieties of maize equal or exceed teosinte in number of leaves just as they do in height. In both maize and teosinte total number of leaves is a character very little affected by changes in the environment. In maize there is usually an intra-variety correlation of about 0.3 between total leaves and height. Corresponding data for teosinte are not available, but the coefficient of 0.69 in the hybrid material affords some evidence of coherence between these characters.

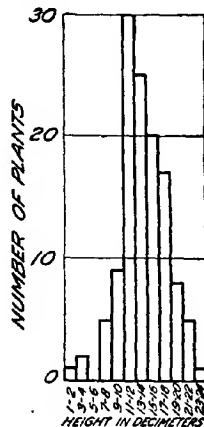


FIG. 1.—Height: frequency distribution of plants in F_2 . Class value, 2 cm.

The larger varieties of maize equal or exceed teosinte in number of leaves just as they do in height. In both maize and teosinte total number of leaves is a character very little affected by changes in the environment. In maize there is

usually an intra-variety correlation of about 0.3 between total leaves and height. Corresponding data for teosinte are not available, but the coefficient of 0.69 in the hybrid material affords some evidence of coherence between these characters.

The correlations of total leaves with other characters are similar to those of height, with the exception that there is no evidence of disherence with nodes silking index. There is also coherence with branch silking first.

HEIGHT OF SUCKER

Measurements were taken from the ground to the tip of the tassel of the tallest sucker or tiller and recorded in decimeters. Tom Thumb almost never produces a sucker. In Florida teosinte there are usually numerous suckers of practically the same height as the main culm. The parent varieties are thus widely separated, but there are varieties of maize with suckers taller than any recorded in teosinte. The mean of the F_2 hybrid plants was 16.2, ranging from 6 to 27, with a practically normal distribution (fig. 3).

The only character outside the group showing a significant correlation with height of sucker is secondary branches. The correlation is in the direction of a coherence.

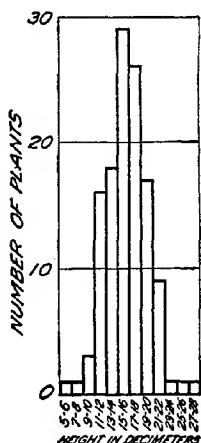


FIG. 3.—Height of sucker: frequency distribution of plants in F_2 . Class value, 2 decm.

culm. This measurement was taken as the best single expression of the tendency to produce tall suckers. Since Tom Thumb almost never produces suckers, the index is practically zero for the male parent of the hybrid. In Florida teosinte the index is usually about 100. In one population of 87, the mean was 99.4, with a range from 90 to 110. In the F_2 hybrid plants the mean was 117, with a range from 50 to 460. The distribution (fig. 4) was unimodal and symmetrical with the exception of a few stragglers probably representing plants with abnormal main culms.

The coherences outside the group are with male secondaries, mixed alicoles, and length of internode on third. The disherences are with three members of the height group, nodes on third branch, two of the tassel measurements, position of best spike, branch silking first, and days to pollen.

There is thus more direct evidence of disherence than of coherence with this character. It should be remembered, however, that the negative correlation of sucker index with height is in a sense physical, since the

SUCKER INDEX

This character was determined by dividing the height of the tallest sucker by the height of the plant and multiplying by 100. It is thus the height of the tallest sucker expressed as a percentage of the height of the main

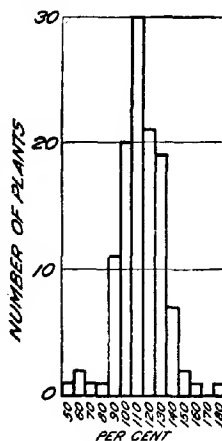


FIG. 4.—Sucker index: frequency distribution of plants in F_2 . Class value, 10 per cent. One plant at 230 and one at 460.

one is a function of the other. The other differences may follow as secondary relations due to this correlation with height.

CIRCUMFERENCE INDEX

In a population of 87, the circumference of the culm of Florida teosinte averaged 61 mm. Under similar conditions the circumference of Tom Thumb was approximately 35 mm. The mean of the F_2 hybrid plants was 56 mm.

Since circumference is so closely associated with the general size of the plant, the circumference measurement was recorded as a percentage of the height of the plant, and the measurement is termed a circumference index.

While in direct measurement the culms of teosinte are thicker than those of Tom Thumb, teosinte is much more slender. In circumference index a high value is therefore a variation toward the maize parent. The mean index of Florida teosinte was 2.7, that of Tom Thumb about 6.0. The mean of the hybrid plants was 4.5, with a normal distribution (fig. 5).

Circumference shows one significant and independent coherence, that with pollen to silk, and a difference with male secondaries.

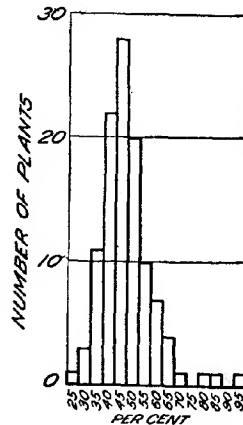


FIG. 5.—Circumference index: frequency distribution of plants in F_2 . Class value, 5 per cent.

NODES WITHOUT BRANCHES

This character is the number of nodes between the lowest branch and the uppermost sucker or the surface of the ground. In teosinte, branches are normally developed in the axils of all leaves on the main culm, except the uppermost. The tendency to suppress branches at the nodes just above the ground appears, however, when the plants are grown under unfavorable conditions. In a planting of Florida teosinte at Chula Vista in 1918 the average number of nodes without branches was 7.6.

In maize there are always a number of nodes without branches between the uppermost sucker and the lowest ear. In Tom Thumb where no suckers are developed, the number can not be definitely determined, since the surface of the ground can not be located with accuracy. But since the average total number of leaves in Tom Thumb is 11 and there is an average of 3 nodes above the single ear and about 5 nodes below the surface of the ground, the mean number of nodes without branches is about 3.

The mean number of nodes without branches in the F_2 hybrid plants was 1.05. The distribution (fig. 6) was far from normal, and there is some indication of two modes. Seventy-nine of the individuals were at zero. Of the remaining 41 plants the largest number, 12, had 3 nodes without branches, with a fairly uniform distribution ranging from 1 to 9.

The significant correlations outside the group were coherences with both of the characters in the male branch group, number of suckers and length of internode on third. The disifferences are with secondary branches and days to pollen.

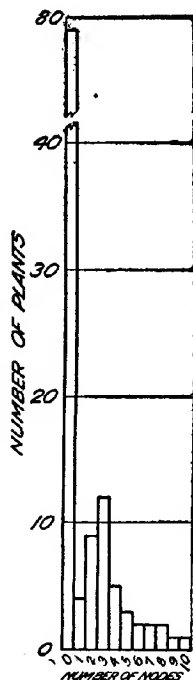


FIG. 6.—Nodes without branches: frequency distribution of plants in F_2 . Class value, one node.

NODES ABOVE GROUP

NODES ABOVE

In teosinte of all varieties there is almost without exception one node above the uppermost branch. In maize the number varies from 8 or 9 to 2 or 3; only in rare and abnormal specimens is it reduced to one. The limits as observed in the Tom Thumb variety are 3 and 5, with the mean at 3.4. This character, while not so constant as total leaves, is less subject to environmental influences than most of the characters recorded.

There is some question of the propriety of considering the number of nodes above the ear in maize as strictly homologous with the number of nodes above the uppermost branch of teosinte. In maize the uppermost branch, or ear, is normally the best developed, while in teosinte the most fruitful branch is usually the third or fourth from the top. See Tables I and II.

If the uppermost branch in teosinte is not homologous with the uppermost branch or ear in maize, the complete absence of any trace of a bud in the axils of the leaves above the upper ear in maize calls for some explanation. It is difficult to believe that branches in the axils of the upper leaves of maize could have been so completely suppressed as to leave neither a trace nor a tendency to reappear as an abnormality. It appears more reasonable to assume that in maize additional nodes have been intercalated or that these sterile nodes in maize, instead of representing a change from the condition found in teosinte, have been derived from a distinct ancestor.

In the first generation there were two plants with one node above and three with two. The range in the second generation was from one to four, with one possibly abnormal plant with none. The distribution

(fig. 7) is decidedly skew, more than half the plants having one, but there is no indication of bimodality.

In maize there is always an intravarietal correlation between nodes above and total number of leaves and other characters that are expressions of size. Since Tom Thumb maize is smaller and has a much smaller number of leaves than teosinte, coherence with these size characters would not be masked by physiological correlations.

It is therefore interesting to note that the tassel characters, which in pure strains of maize are positively correlated with nodes above, are here negatively correlated, affording clear evidence of coherence. There are also significant correlations in the direction of coherence with the male branch characters and node silking first. There are no significant disherences.

NODES ABOVE ON THIRD

In all varieties of teosinte the number of nodes above the uppermost secondary on the third branch is one, as on the main culm. In maize the value will depend on what is considered the homologue of the third branch from the top in teosinte. Taken strictly, the upper branch in maize is the ear, and the third branch from the top, when such exists, would be an earlike branch that in some types would partake somewhat of the nature of a sucker. If sufficiently suckerlike, the number of nodes above the uppermost secondary of such a branch would correspond to those of the main stalk, that is, the range would be from 3 to 8. If, however, the ear of maize be assumed to correspond to some branch below the uppermost in teosinte, those above the ear having been suppressed, the number of nodes above the uppermost secondary would be much greater, for in this case the branch would be an ear and the secondary branches would be the secondary ears which almost invariably are borne in the axil of the lowest husk. In any case the number would be larger in maize than in teosinte.

This character was recorded for three of the F_1 plants. In two of these the number was 1; in the other it was 2. The average number in the F_2 hybrid plants was 1.78, with no indication of bimodality. The distribution (fig. 8) is much less skew than for the nodes above on the main culm, the mode being at 2. In its correlations, this character is similar to nodes above on the main stalk.

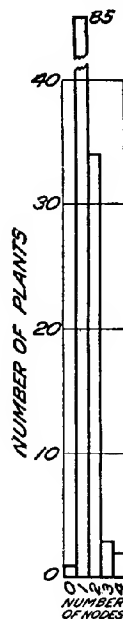


FIG. 7.—Nodes above: frequency distribution of plants in F_2 . Class value, one node.

NODES ON THIRD

This character is instructive chiefly as a means of throwing light on the homologies between the branches of teosinte and maize and as a means of calculating the average length of internodes on the third branch described below.

If each husk on an ear of maize represents a node, the third branch from the top, which would still be earlike, would have even in Tom Thumb from 6 to 8 nodes. In other varieties this number would be even larger. On the other hand, if the leaves from which the husks are derived have been subdivided, thus increasing the apparent number of nodes, the number of nodes on this branch of the hybrids might be expected to agree pretty closely with the number in teosinte, which varies from 2 to 5. The modal number in the F_2 hybrid plants was 6, the mean was 7.15, with a range from 4 to 14. There was no indication of bimodality (fig. 9). There was no indication in the hybrid plants that leaves were subdivided, each leaf being borne on a well-defined internode. The increased number of nodes over that of teosinte goes to support the idea that each of the husks on an ear of maize represents an internode of the branch.

In common with the other characters of this group, the correlations with secondary branches and prophyllary spikes would seem significant coherences. In these correlations a high value of one character is correlated with a low value of the other, and any general tendency to vigor would reduce the correlation.

FIG. 8.—Nodes above on third: frequency distribution of plants in F_2 . Class value, one node.

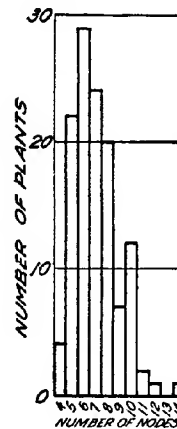
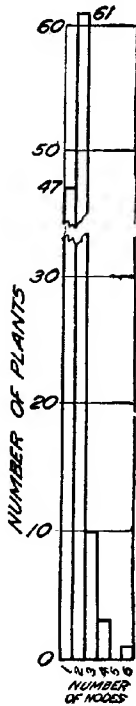


FIG. 9.—Nodes on third: frequency distribution of plants in F_2 . Class value, one node.

The correlations with position of best spike and node silking first are of doubtful significance, there being an obvious physiological connection between these characters and the number of nodes in the third branch.

All the significant disherent correlations are of a nature that suggests a physiological explanation.

TASSEL GROUP

PRIMARY BRANCHES

Primary tassel branches are much more numerous in teosinte than in any but the very largest varieties of maize. In the Tom Thumb variety the maximum number observed was 9, and this falls far below the number in any normal teosinte plant. The mean number for Tom Thumb and Florida teosinte grown under similar conditions was 4.6 and 12.5, respectively. In the F_1 plants the number ranged from 16 to 20. In the second generation the mean was 16.7 with a range from 5 to 29. The distribution (fig. 10) was symmetrical and unimodal.

There are two significant independent coherences, one with characters of the height group and the other with days to pollen. There are also two disherences, one with number of single female alicoles, the other with length of internode on third. The apparent disherence with sucker index is probably associated with the negative correlation of sucker index with the other height characters.

SECONDARY BRANCHES

Teosinte has a much larger number of secondary tassel branches than maize. The specific ranges of the parents may overlap, but the Tom Thumb variety seldom develops secondary branches, while in Florida teosinte the mean number was 10.3.

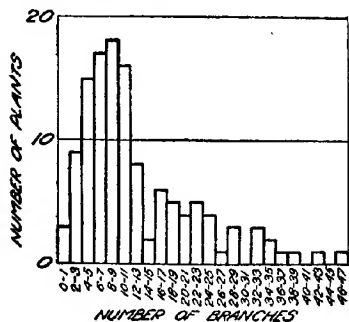


FIG. 11.—Secondary branches: frequency distribution of plants in F_2 . Class value, two branches.

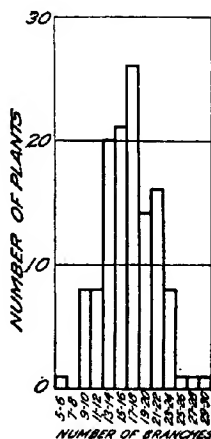


FIG. 10.—Primary branches: frequency distribution of plants in F_2 . Class value, two branches.

In the F_2 hybrid plants the mean was 12.6, with a range from 0 to 46. The distribution (fig. 11) is very skew, the mode being near 8, but there is little evidence of more than one mode.

This character shows more evidence of coherence than does the character primary branches. It is closely correlated with three of the measurements of height.

There is the same negative correlation with sucker index; and in addition the positive correlation with nodes without branches, which is in the direction of a disherence, is here above 0.25.

A most striking example of coherence is the negative correlation of secondary branches with all three of the nodes above group. The other coherences are with male branches, branch silking first, and days to pollen. The only clear evidence of disherence is with male secondaries and length of internode on third.

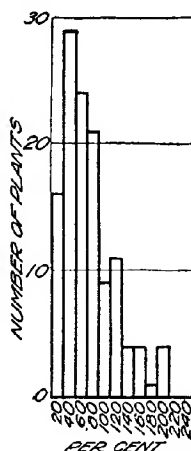


FIG. 12.—Secondary index: frequency distribution of plants in F_2 . Class value, 20 per cent. One plant at 340.

SECONDARY INDEX

This character, which is the number of secondary branches expressed as a percentage of the total branches, distinguishes more sharply between maize and teosinte than does the direct measurement of either primary or secondary branches. Secondary tassel branches are relatively as well as absolutely much more numerous in teosinte than in maize. In teosinte they equal or exceed the number of primary branches, while in maize the number of secondaries equals the number of the primaries only in some of the large tropical varieties.

In the F_2 hybrid plants the mean was 70, with a very skew distribution (fig. 12) but with no evidence of more than one mode.

The correlations are similar to those with the direct measurements of tassel branches, except the additional coherences with number of alicoles and rows in central spike.

TASSEL BRANCHES ON THIRD

In teosinte the modal number of tassel branches on the third branch from the top is two. When teosinte is grown under rather unfavorable conditions where the number of branches is reduced, there is evidence of a bimodal distribution, in that plants with two branches or none are more numerous than plants with a single branch. In maize the number is zero, since all branches from the upper nodes of maize are normally unbranched.

In the F_2 hybrid plants the mean was 6.1. The distribution (fig. 13) was skew, with slight indication of two modes.

Although closely correlated with the tassel characters of the main stalk, this character shows no significant correlations outside the group except with number of nodes on third. This is in the direction of a disherence; but the relation is doubtless physiological, since both characters would be similarly affected by changes in general vigor.

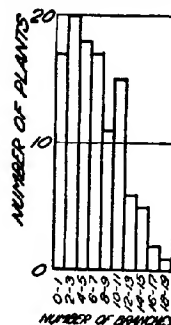


FIG. 13.—Tassel branches on third: frequency distribution of plants in F_2 . Class value, two branches.

The five tassel characters form a closely correlated group. With few exceptions all the members of the group show similar relations with other characters. With the exception of secondary index, all are direct measurements that might be expected to increase with increased vigor; and were it not for this character the correlations with the direct measurements in the height group might be considered physiological. The same may be said of the nodes above group. The disherent correlation of tassel branches on third with nodes on third branch is also physiological, since a highly developed third branch would naturally have a larger number of tassel branches.

The clearest evidences of coherence are the correlations of secondary index with rows in central spike and that between secondary branches and branch silking first. Disherence is indicated by the negative correlations between all the tassel characters and the two characters male secondaries and length of internode on third.

MALE BRANCH GROUP

MALE BRANCH INDEX

This character was calculated by dividing the number of branches terminating in staminate inflorescences, excluding suckers, by the total number of leaves and multiplying by 100. It is thus the number of male branches expressed as a percentage of total leaves or internodes of the main culm.

In normal maize none of the branches above the suckers bear staminate flowers, although staminate tips and perfect flowered spikelets are common abnormalities. In teosinte all primary branches normally end in a staminate inflorescence. There is, then, no overlapping of either of the varieties or species with respect to this character.

The F_2 hybrid plants ranged from 0 to 71 with the mean at 37. The distribution (fig. 14) is practically symmetrical and clearly unimodal.

There are four significant correlations, all in the direction of coherences. They are with nodes without branches, nodes above, alicole index, and branch silking first. Except in the correlation with alicole index, a physiological explanation is suggested.

MALE SECONDARIES

As a measure of this character, all secondary branches on the third branch from the top of the plant that bore staminate spikelets were counted.

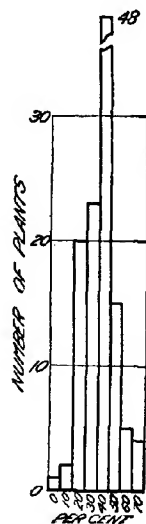


FIG. 14.—Male branch index: frequency distribution of plants in F_2 . Class value, 10 per cent.

In normal maize there would be no secondary branches bearing staminate spikelets. In Florida teosinte the number is usually 2 or 3. In the F_2 hybrid plants the mean number was 2. The range was from 0 to 8. Nearly half the plants had no staminate secondaries and there is almost no indication of a second mode (fig. 15).

Nearly all the significant correlations not readily assignable to physiological relations are disherent. Thus height, total leaves, and circumference index in the height group, secondary branches and secondary index in the tassel group, branch silking first, and days to pollen all show disherent correlations. Many of these are related, since they would be similarly affected by changes in vigor, but it is difficult to

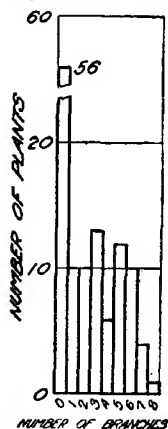


FIG. 15.—Male secondaries: frequency distribution of plants in F_2 . Class value, one branch.

understand why increased vigor should result in a smaller number of male secondaries; and the negative correlation with secondary index is difficult to understand as other than genetic.

The absence of correlation between male secondaries and male branch index, which are placed in the same group because both are measures of the tendency to produce staminate spikelets, is in itself an indication of disherence.

CHARACTERS OF THE PISTILLATE INFLORESCENCE ALICOLE GROUP

To discuss the characters of the pistillate inflorescence of the hybrids between maize and teosinte, a short preliminary description is necessary.

In maize both staminate and pistillate spikelets are borne in pairs. In the pistillate inflorescence each pair of spikelets occupies a pit or alveolus. In the staminate inflorescences there is only a faint suggestion of an alveolus. In teosinte the arrangement of the staminate spikelets is like that in maize; but in the pistillate inflorescence the spikelets are borne singly, each occupying a highly specialized alveolus. In hybrids of maize and teosinte, all permutations of the above arrangements occur, and to facilitate description the term alicole is used for the spikelet or spikelets arising from a single alveolus or having a common origin. Thus an alicole may consist of one or more staminate spikelets, one or more pistillate spikelets, or both pistillate and staminate spikelets.¹

¹ For a more complete discussion of the pistillate inflorescence of teosinte and maize hybrids see COLLINS, G. N. STRUCTURE OF THE MAIZE EAR AS INDICATED IN *ZEA-EUCHLAENA* HYBRIDS. In *Jour. Agr. Research*, v. 17, no. 3, p. 127-135, 1 fig., pl. 16-18. 1919.

In normal maize the number of rows of alicoles is always half the number of rows of grains. In the hybrid plants, however, 4-rowed spikes may consist of either two rows of alicoles, each with two seeds, or four rows of alicoles, each with a single seed. Plants exhibiting the range of variation with respect to the pistillate inflorescence are shown in Plates 2 to 5.

As a basis of comparing the pistillate inflorescences of the hybrid plants, the best-developed spike on the third branch from the top of the plant was chosen and the number and nature of the alicoles were recorded. To eliminate as far as possible differences associated with the size of the spike, the number of alicoles of the classes single male, double male, single female, double female, and mixed (one male and one female) was expressed as a percentage of the total number of alicoles in the spike.

DOUBLE MALE ALICOLES

Neither maize nor teosinte normally produces male spikelets in the pistillate inflorescences. In the F_2 hybrids, however, out of 123 plants in which the nature of the pistillate inflorescences was determined, 18 had some alicoles with two staminate spikelets, in 2 plants the number being as high as 50 per cent (fig. 16).

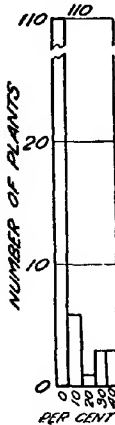


FIG. 17.—Mixed alicoles: frequency distribution of plants in F_2 . Class value, 10 percent.

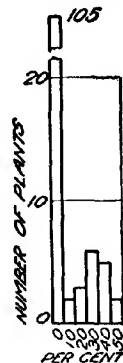


FIG. 16.—Double male alicoles: frequency distribution of plants in F_2 . Class value, 10 percent.

MIXED ALICOLES

Mixed alicoles are not a character of either maize or teosinte. There were, however, 13 F_2 hybrid plants with mixed alicoles, the highest percentage being 40 (fig. 17).

SINGLE FEMALE ALICOLES

Single female alicoles are a universal character of teosinte, while in maize no variety is known in which the seeds are not paired. Single female alicoles may occur in rare instances on a part of an ear of maize where the number of rows is reduced toward the tip.

In the F_2 hybrid plants, although there was practically a continuous series from 0 to 100 per cent, there were distinct indications of a tendency to segregate into the two parental forms, there being two modes, one at 0, the other at 100 (fig. 18). The numbers at these two modes were 34 and 12, indicating that the maize character is dominant.

In this connection it should be recalled that in the F_1 plants the alicoles of the pistillate inflorescence all bore two spikelets.

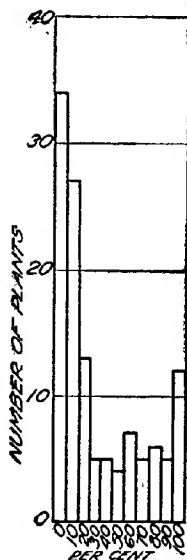


FIG. 18.—Single female alicoles; frequency distribution of plants in F_2 . Class value, 10 per cent.

or the double alicoles of maize to predominate is the nearest approach to Mendelian behavior among the characters recorded.

The measurements of the alicole group form such a closely related series that their correlations may be discussed together. Significant coherences are shown with both characters of the male branch group and with number of alicoles, rows in the central spike, and number of suckers. The only significant disherence is between single female alicoles and primary branches.

Some of the coherences may be of a physiological nature, but the almost complete absence of any evidence of disherence with this group of characters which most nearly approaches an alternative method of inheritance should perhaps be noted.

DOUBLE FEMALE ALICOLES

Double female alicoles may be considered allomorphic to single alicoles, but owing to the occurrence of plants with small percentages of double male and mixed alicoles the percentages are not exact reciprocals. There is, however, the same bimodality (fig. 19), the numbers indicating the dominant nature of this character.

ALICOLE INDEX

With the idea that mixed and male alicoles were in the nature of abnormalities, the number of single female alicoles was expressed as a percentage of the combined single and double female alicoles. There were 36 plants with no single female alicoles and 19 with no double female alicoles.

If the individuals are separated into two groups at the low point in the bimodal curve, which is 50 per cent, the numbers are 83 below this point and 37 above (fig. 20).

The tendency for either the single alicoles of teosinte

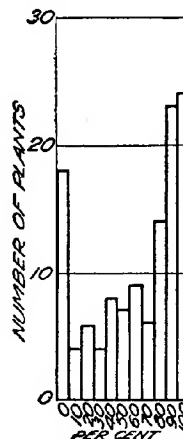


FIG. 19.—Double female alicoles; frequency distribution of plants in F_2 . Class value, 10 per cent.

NODES SILKING GROUP

NODES SILKING ON THIRD

This character, which is the number of nodes producing silk on the third branch from the top, was chosen with the idea of indicating the distinction between teosinte and maize with respect to the production of secondary fruiting branches on the upper part of the main culm. In all varieties of maize, branches from the upper part of the plant are normally simple, though secondary ears are a common abnormality. The branches of the ears of *Zea ramosa* are not subtended by bracts, and they arise from separate internodes only in the sense that branches from the tassel represent separate internodes.

Teosinte normally produces silks at two or three nodes of the third branch from the top. The average for 87 Florida teosinte plants was 2.3, with a range from 0 to 4. Since there are seldom more than 4 nodes on the third branch, the difference is more significant than the numbers would make it appear.

In the F_2 hybrid plants the range was from 0 to 10, with the mean at 5.5. The distribution (fig. 21) is practically symmetrical and unimodal.

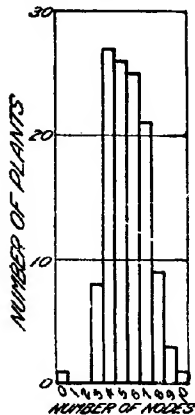


FIG. 21.—Nodes silking on third; frequency distribution of plants in F_2 . Class value, one node.

There are three significant correlations with this character, but all appear to be physiological. The positive correlation with nodes on third branch is obviously almost physical; that with male secondaries is only slightly less so. The correlation with position of best spike of 0.47 might be considered a disherence, but it seems not unreasonable that with more nodes silking the best spike would, on the average, be located farther from the base. This is supported by the negative correlation of node silking index with position of best spike.

NODES SILKING INDEX

The number of secondary branches silking as expressed in the preceding character is very definitely associated with the length of the third branch, the branches with more nodes having the greatest number

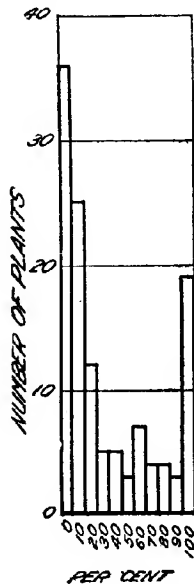


FIG. 20.—Ailicole index; frequency distribution of plants in F_2 . Class value, 10 per cent.

silking. With a view to obtaining an expression of the tendency to produce secondary branches independent of the length of the primary branch, the number of nodes silking on the third branch was expressed as a percentage of the total number of nodes on the branch.

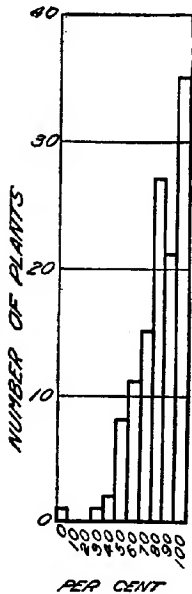


FIG. 22.—Nodes silking index: frequency distribution of plants in F_2 . Class value, 10 per cent.

character is therefore one that is sharply contrasted in the parents. Two of the F_1 plants in which this character was recorded each produced a single prophyllary spike.

In the second generation, 23 of the plants either had no prophyllary branch or it was not sufficiently developed to bear a spike. In 23 plants the branch consisted of an unbranched spike. The remaining 68 plants had from 2 to 14 spikes. The mean number for all plants was 3.1, the distribution (fig. 23) being skew but with no evidence of more than one mode. The three significant correlations are all coherent, but all may be physiological.

In teosinte the percentage is normally 100,¹ in maize 0. In F_2 hybrid plants the range was from 0 to 100. The modal number was 100, with the numbers diminishing with fair regularity to 0 (fig. 22). The mean was 78.

With the exception of the negative correlation with position of best spike, all the coherences are obviously physiological. On the other hand, the disherent correlation with height would appear to be genetic.

PROPHYLLARY GROUP

PROPHYLLARY SPIKES

Prophyllary branches are rare in maize and have never been observed in Tom Thumb. In varieties where prophyllary branches do occur they are simple. In teosinte, prophyllary branches are always well-developed; and in Florida teosinte, the average number of spikes is 6.3, with a range from 3 to 11. The disposition of the spikes in teosinte is shown in Table I. This

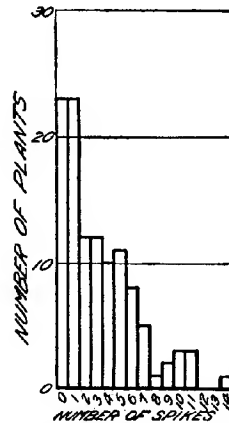


FIG. 23.—Prophyllary spikes: frequency distribution of plants in F_2 . Class value, one spike.

¹ This follows from the fact that although there is no branch produced in the axil of the uppermost leaf there is a fruiting branch borne in the axil of the prophyllum.

LENGTH OF PROPHYLLARY

This character is closely associated with the number of spikes in the prophyllary, and like that character it distinguishes sharply between the parental varieties and species.

The mean length of the prophyllary branch in 87 plants of Florida teosinte was 10.8 cm. The mean length in the F_2 hybrid plants was 13.4 cm. There was some evidence of two modes (fig. 24), one at 0, the other at 13.

There are three significant coherent correlations—namely, with male secondaries, nodes silking index, and length of internode on third.

The correlation with position of best spike is also significant but disherent.

Although prophyllary spikes and length of prophyllary have a positive correlation of 0.59, the first is negatively correlated with position of best spike while the correlation with the second is negative. Thus, as the prophyllary branch becomes longer there are more spikes, but they are smaller.

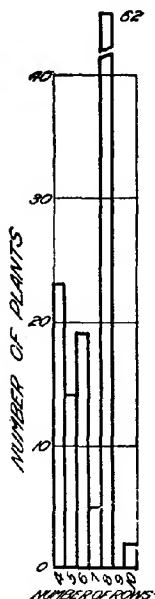


FIG. 25.—Rows in central spike: frequency distribution of plants in F_2 . Class value, one row.

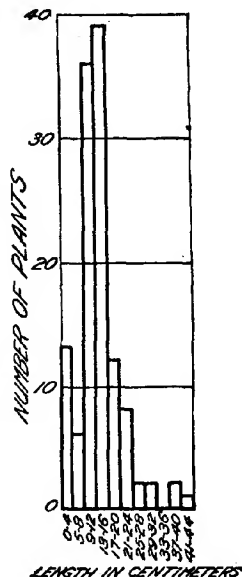


FIG. 24.—Length of prophyllary: frequency distribution of plants in F_2 . Class value, 4 cm.

NUMBER OF ROWS GROUP

ROWS IN CENTRAL SPIKE

The number of rows of spikelets in the central spike of the tassel is a close homologue of the number of rows of seeds in the pistillate inflorescence. At first thought this might seem not to be the case in teosinte where all the spikes of the staminate inflorescence are 4-rowed and those of the pistillate inflorescence are 2-rowed. This apparent disagreement is occasioned by the suppression of one of each pair of spikelets in the pistillate inflorescence, there being in each instance 2 rows of alicoles.

In maize, so far as observed, plants with 8-rowed ears always have 8-rowed central spikes. With the higher number of rows the arrangement in the central spike becomes indistinct.

In pure teosinte there is, properly speaking, no central spike, since the last division of the inflorescence gives two equal branches, each bearing 4 rows of spikelets. In the F_2 hybrid plants there were all stages from the condition found in teosinte, which was recorded as 4-rowed, to a well-formed central spike; and the number of rows is one of the best measures of the differentiation into a central spike. In many plants the number of rows was greater by 2 at the base of the spike than at the top. In such instances the intermediate odd number was assigned,

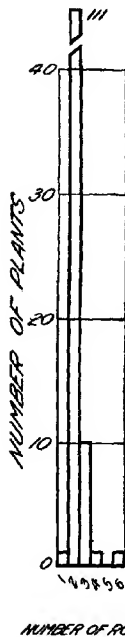


FIG. 26.—Rows of alicoles: frequency distribution of plants in F_2 . Class value, one row.

The distribution (fig. 25) was slightly bimodal, the modes being at 4 and 8, with the mean at 6.6.

All the significant correlations with this character are coherences, though none are very close.

It is of interest that the only other tassel character showing coherence with rows in central spike is secondary index. All other tassel measurements might be expected to increase with increased vigor; and since coherences would appear as negative correlations, any tendency for rows of central spike to increase with size would reduce the coherences. Two of the five alicole characters show significant coherences. There is also a significant coherence with number of alicoles.

ROWS OF ALICOLES

The number of rows of alicoles in the pistillate inflorescence is one of the most striking differences between teosinte and maize. In all varieties of teosinte the number is 2. The lowest number in maize is 4, as is characteristic of all 8-rowed varieties. In the large-eared varieties the number reaches 18. All the F_1 plants had uniformly 2 rows of alicoles, indicating the dominance of the teosinte character.

In the second generation 111 out of 123 plants also had 2 rows (fig. 26). This number is 19 in excess of the number expected if the character were behaving as a simple Mendelian unit. The uniformity of the F_2 plants with respect to this character made it impossible to determine correlations, but of the 12 plants with more than 2 rows of alicoles all but 1 had more than 4 rows in the central spike.

INDEPENDENT CHARACTERS

POSITION OF BEST SPIKE

In maize the pistillate spike is terminal on the branch. In teosinte there are usually a number of spikes of nearly equal size, the prophyllary branch usually producing spikes as large as any on the branch.

In the F_2 hybrid plants this character was determined on the third branch. The nodes were numbered from the base of the branch, the prophyllary branch being recorded as 0. The range was from 0 to 9, with the mode at 3. The mean was 2.22. The distribution (fig. 27) was decidedly skew, but there was little evidence of more than one mode.

In its relation to other characters, this character is very irregular. The large number of disherent correlations may indicate that the terminal position of the pistillate inflorescence in maize is not inherited as a tendency for the lateral pistillate inflorescences to be located near the top of the branch. When secondary ears are developed in maize they are always near the base of the branch, and the expression of this tendency in inheritance may be the explanation of the apparently disherent correlations.

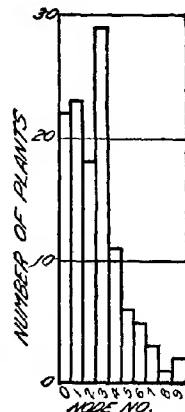


FIG. 27.—Position of best spike: frequency distribution of plants in F_2 . Class value, one node.

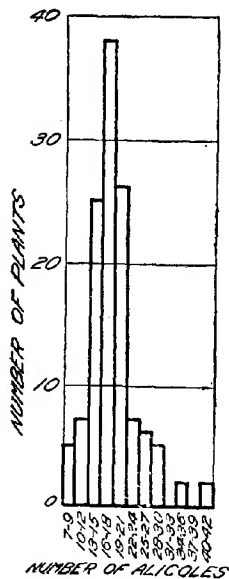


FIG. 28.—Number of alicoles: frequency distribution of plants in F_2 . Class value, three alicoles.

NUMBER OF ALICOLES

The number of alicoles in a well-developed spike of Florida teosinte is 7. In Tom Thumb maize the number is seldom less than 100. The lowest number recorded in a normal ear of maize is 50, in a Peruvian variety from the region of Lake Titicaca. This is, therefore, one of the characters in which there is no approach to overlapping in the parental species.

The F_1 plants had spikes with from 11 to 18 alicoles. In the second generation the range was from 7 to 40. The mean was 17.85 with nearly symmetrical distribution (fig. 28), the mode being at 16.

¹The significant coherences with characters in the alicole group afford perhaps the most direct evidence that has appeared that the characters of the pistillate inflorescence tend to be inherited as a unit.

The correlation with rows in the central spike is perhaps physiological. There are no significant disherences.

NUMBER OF SUCKERS

Florida teosinte is characterized by a large number of suckers or branches that arise from below or near the ground. In a population of Florida teosinte at Chula Vista, grown in 1917, the average number of suckers was 14. Tom Thumb never produces suckers on normal plants, and no variety of maize has been studied that produces as many suckers as teosinte. The expression of this character is so dependent on environmental conditions, however, that statements regarding the range in maize would have little value. The most vigorous F_1 plant produced 11 suckers.

In the second generation the range was from 0 to 32, with the mode at 13 and the mean at 11.7. There is no evidence of more than one mode (fig. 29).

There are, in all, three significant correlations with this character, nodes without branches, single female alicoles, and double female alicoles—

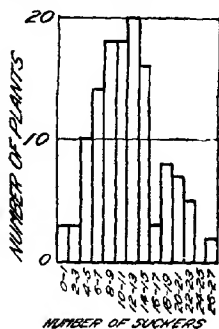


FIG. 29.—Number of suckers: frequency distribution of plants in F_2 . Class value, two suckers. One plant at 32.

all of them coherences. The first of these is obviously physiological, since a large number of suckers and a small number of vacant nodes are both expressions of a tendency to produce branches. The other two are practically different expressions of the same character and indicate a coherence.

BRANCH SILKING FIRST

In recording this character the primary branches were counted from the top. In maize the uppermost branch is the first to silk, except in rare instances where the second ear may silk a day or two in advance of the first. In teosinte the fourth or fifth branch is usually the first to silk. This character therefore distinguishes sharply between the parents with respect to both the variety and the species.

The F_2 hybrid plants ranged from 1 to 5, with equal numbers at 1 and 2. The mean was 1.9, the distribution (fig. 30) was skew and unimodal.

With the height group there are two significant correlations, one a coherence with total leaves, the other a disherence with sucker index. This disherence doubtless results from the negative correlation between total leaves and sucker index. The partial correlation of node silking first

with either total leaves or sucker index, with the other character constant, is less than three times the probable error. There are also significant correlations with all the characters of the nodes above group. These correlations are in a sense physical, since the value representing the node silking first must always be greater than the nodes above. In the male branch group there is a significant coherence with male branch index and a disherence with male branches on third. In addition there are significant coherences with secondary branches, position of best spike, and days to pollen.

DAYS TO POLLEN

Although profoundly influenced by the environment, the length of time before pollen is shed is the best measure of the length of season required for development. Under similar conditions there are few varieties of maize that require so long a time to mature as Florida teosinte, and Tom Thumb is one of the earliest varieties of maize. The period for Florida teosinte under conditions similar to those where the hybrid plants were grown was 162 days, and for Tom Thumb 43 days.



FIG. 31.—Days to pollen: frequency distribution of plants in F_2 . Class value, 10 days.

The average time for the F_1 was 98 days. The F_2 plants averaged 112 days, with a single mode at 96 days (fig. 31). The earliest plant flowered in 71 days, and the latest required 165 days from the date of planting.

With characters of the height group there are two significant coherences, height and total leaves, and two significant disherences, sucker index and nodes without branches.

The correlation with height is an especially striking coherence, since the positive correlation is 0.47 while the same correlations in both teosinte and Tom Thumb are negative, being 0.46 and 0.11, respectively. Days to pollen and total leaves in teosinte have a correlation of 0.14, a correlation significantly lower than the 0.79 of the hybrids.

The negative correlation with sucker index appears to result from the negative correlation of sucker index with total leaves.

The coherence with nodes above on third is barely significant and may be physiological. There are significant coherences with three of the four tassel measurements, and in Tom Thumb the three tassel measurements recorded are all negatively correlated with days to pollen.

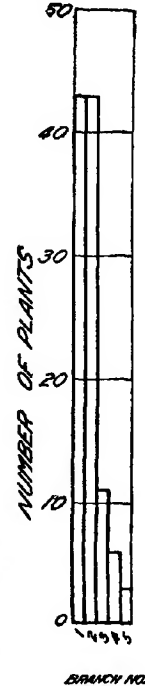


FIG. 30.—Branch silking first: frequency distribution of plants in F_2 . Class value, one branch.

There are also significant coherences with number of alicoles and node silking first. The disherent correlations with male secondaries and length of internode on third appear to be genetic. That with length of internode on third is the highest coefficient with days to pollen.

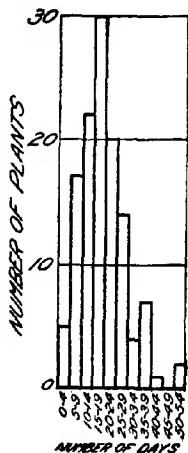


FIG. 32.—Pollen to silk: frequency distribution of plants in F_2 . Class value, five days.

ing from 0 to 53 days, with the mean at 18.3. The distribution (fig. 32) was symmetrical and unimodal.

There are but two significant correlations with this character, both coherences. These are with circumference index and position of best spike. The latter is in one sense physiological.

LENGTH OF INTERNODE ON THIRD

This character was determined by dividing the length of the third branch by the number of internodes. The branches from the upper nodes of a maize plant are much shortened. An accurate measure is impossible on account of the difficulty of accurately determining the number of nodes. In Tom Thumb it would, however, be somewhat less than 1 cm., and in normal maize plants of any variety it would scarcely exceed 3 cm. In a normally developed teosinte plant the internodes of the third branch will average about 10 cm. This character was not recorded in the first generation. In the F_2 plants the mean was 10.9 cm. The range was from 2 to 22, with practically a normal distribution (fig. 33).

POLLEN TO SILK

Maize is normally proterandrous. There are, however, proterogynous strains of maize, and proterogynous individuals in almost any strain are not uncommon. Tom Thumb is normally proterandrous by about 10 days. Florida teosinte appears to be normally proterogynous. It has always been so in our experiments; and an examination of the fields at Clarcona, Fla., in 1914, showed the plants to be silking from 7 to 10 days before pollen. Durango teosinte, on the other hand, under most conditions is proterandrous.

In both maize and teosinte this character is especially susceptible to environmental influence. The F_1 plants were decidedly proterandrous at both Lanham and Chula Vista. None of the F_2 plants were proterogynous, the proterandry rang-

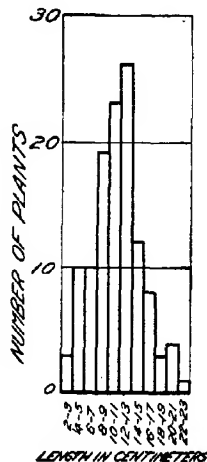


FIG. 33.—Length of internode on third: frequency distribution of plants in F_2 . Class value, 2 cm.

This character might be expected to be closely related to number of nodes on third, since in a mathematical sense it is a function of that character. However, the correlation between length of internode on the third branch and nodes on third is -0.05 .

Length of internode on third shows a larger number of significant correlations than does any other character.

A high expression of the character might be expected to be associated with increased general vigor, but many of the correlations are in the opposite direction. There is distinctly more evidence of disherence than of coherence. In fact, three of the four significant coherences may be physiological, while most of the disherences are not to be explained in this way.

Especially significant are the pronounced negative correlations with height and total leaves. Only slightly less striking are the negative correlations with two of the tassel characters.

DISCUSSION OF CORRELATIONS

It would be very difficult, if not impossible, to determine with accuracy the number of independent correlations. The interrelation of the characters is of a most intricate nature; and even if the data warranted the calculation of the partial correlations of each pair with all other characters constant, the facts would still be very inadequately represented. Correlations take no account of causation or the sequence in which characters are determined.

It is clear that the values of some characters are directly influenced by others, the relation being causal in nature. Thus the number of total leaves acts as a limiting factor to the number of branches ending in male flowers, and the correlation of any character with number of branches ending in male flowers may to some extent follow as a secondary relation to the correlation between the character in question and total leaves. On the other hand, it is obviously absurd to reason that branches ending in male flowers may influence the total leaves; and to correct the correlation with total leaves by making branches ending in male flowers constant might represent a mathematical relation, but the determination would have no biological significance.

An attempt was made to determine whether the more striking disherent correlations might result from the correlations of other interrelated characters. Thus height and the index of nodes silking on the third branch, which showed a disherent correlation of -0.46 , were found to be mutually correlated with four other characters to an extent that would materially influence the correlation in question. The partial correlation of height and index of nodes silking on the third branch with all of the

four correlated characters constant was found to be -0.69 . Such relations must stand, therefore, as disherences so far as the recorded data are concerned.

A study of the correlations shows that within wide physiological limits there are no incompatible combinations. On the other hand, all the characters are in a sense interrelated. Having in mind the theory that ascribes the determinants of characters to definite locations on the chromosomes, the authors examined the correlations to determine whether there were groups of characters between which there were no significant correlations. No such grouping was apparent, and it was possible to arrange the entire series so that they formed a single group with no correlation lower than ± 0.31 .

If the results of this experiment are interpreted in terms of the theory mentioned above, it follows from the blended character of the inheritance that practically all the characters result from the combined action of numerous factors. The failure of the characters to fall into groups the members of which are genetically correlated further indicates that the factors for the individual characters must be distributed in different chromosomes.

CORRELATION AMONG DESIRABLE CHARACTERS

Among the characters measured, a certain few are indicative of desirable characteristics from the standpoint of a forage plant. The more important of those are (1) total leaves, indicative of the luxuriant foliage of the teosinte, (2) circumference index, a small circumference in proportion to the height indicating the slender, edible stalks of the teosinte, (3) nodes silking on third branch, indicating the profuse production of seed of the teosinte, (4) number of suckers, indicating the abundant production of forage of the teosinte, (5) male branch index, indicative of the numerous branches of teosinte, (6) number of alicoles in the best spike, indicating the large pistillate inflorescences of maize, (7) rows in the central spike, indicating the many-rowed inflorescences of maize, and (8) days to pollen, a low value indicating the short season of maize.

The interrelation of these selected characters is shown in Table VI. Of the 27 combinations of these characters there are 9 in which both of the desired characters are possessed by teosinte, 3 in which both are possessed by maize, and 15 where it is desired to combine teosinte and maize characters.

TABLE VI.—Correlation of characters desirable in a forage plant^a

Characters considered.	Circumference index.	Nodes silking on third.	Number of suckers.	Male branch index.	Number of alicoles.	Rows in central spike.	Days to pollen.
Total leaves.....	-0.31	0.05	-0.10	-0.07	-0.18	-0.14	0.79
Circumference index.....		.00	.19		.12	.03	.17
Nodes silking on third.....			.01	.19	.05	.03	.07
Number of suckers.....				.14	.11	.02	.09
Male branch index.....					.06	.04	.03
Number of alicoles.....						.37	.29
Rows in central spike.....							.09

^a Figures in bold-face type indicate coefficients of correlation between the characters where a combination of teosinte and maize characteristics is desired.

Of the 15 character pairs where new combinations are desired, there is only one significant correlation. This is days to pollen and total leaves. In this one instance the relation is in a sense physical, since there is obviously a physical limit to the number of leaves that can be developed in a very short season. The indications from this comparison are, therefore, that coherence presents few obstacles to the securing of desired combinations. (Pl. 2; 6, A, B.)

Another view of the comparative independence of the characters may be gained by an examination of the plants that were most like maize or teosinte with respect to some of the more important characters. Table VII is provided to make this possible. Each pair of columns gives the measurements for two plants, one of which was the most like maize and the other the most like teosinte with respect to the character named at the head of the column.

TABLE VII.—Comparison of individual plants, showing the extreme variations toward maize and teosinte, respectively^a

Characters considered.	Average.	Height.		Total leaves.		Height of sucker.		Sucker index.		Circumference index.		Male branches. ^b		Number of suckers.		Number of alicoles.		Days to pollen.		Rows of alicoles.	
		Maize-like (plant 19).	Teosinte-like (plant 38).	Maize-like (plant 17).	Teosinte-like (plant 62).	Maize-like (plant 78).	Teosinte-like (plant 20).	Maize-like (plant 78).	Teosinte-like (plant 19).	Maize-like (plant 115).	Teosinte-like (plant 64).	Maize-like (plant 40).	Teosinte-like (plant 62).	Maize-like (plant 81).	Teosinte-like (plant 35).	Maize-like (plant 150).	Teosinte-like (plant 24).	Maize-like (plant 27).	Teosinte-like (plant 38).	Maize-like (plant 36).	Teosinte-like (plant 40).
Height.....	14	4	23	14	22	14	20	14	4	8	17	...	22	9	14	15	17	9	23	14	11
Total leaves.....	73	21	33	13	38	23	26	23	22	...	23	29	38	19	29	23	38	21	33	19	24
Height of sucker.....	10	20	21	17	23	6	27	6	20	18	17	7	23	0	16	15	19	13	21	15	12
Sucker index.....	112	400	90	130	100	50	140	50	160	230	100	...	100	0	110	110	110	140	90	110	110
Circumference index.....	4.5	...	3.5	...	4.4	4.0	...	4.0	...	9.1	2.4	...	4.4	3.5	4.3	5.5	...	5.0	3.5	4.0	3.0
Male branches ^b	8	9	5	12	21	5	5	5	9	18	9	0	21	5	6	10	9	5	9	5	7
Number of suckers.....	12	14	8	21	7	4	15	4	14	11	14	2	7	0	23	18	20	15	8	3	15
Number of alicoles.....	18	19	17	17	34	21	13	21	19	23	21	29	34	17	9	40	7	13	17	30	9
Days to pollen.....	112	103	105	103	121	100	108	100	103	142	106	...	121	129	13	100	131	69	165	85	116
Rows of alicoles.....	2.4	2	2.5	2	3	2	2	2	2	3	2	2.4	3	2.5	4	2	2	2.5	3	2	2

^a Each pair of columns gives the measurements of two plants, one of which was most like maize and the other most like teosinte with respect to the character given at the head of the columns. The value of the character for which the plant was selected is given in bold-face type. For description of units of measurement, see p. 7-8.

^b The number of primary branches that terminate in a staminate panicle, exclusive of suckers.

¹ It may seem that, except for the character chosen, the values for the most part depart little from the mean values. For example, under total leaves the most maize-like plant which had 13 leaves was particularly maize-like in no other character. It was even below the average in number of alicoles in the best spike and had almost the maximum number of suckers. On the other hand, the plant with the greatest number of leaves had also the greatest number of male branches but was decidedly maize-like with respect to number of suckers and number of alicoles.

CONCLUSIONS

The genetic relations of the principal characters of maize and teosinte were investigated in a cross between a small variety of pop corn and Florida teosinte, a large forage grass generically distinct from maize. The F_1 plants showed characters which, for the most part, were intermediate between those of the parents.

The F_2 plants were also intermediate, with a greatly extended range of variation. Thirty-three of the characters that differentiate the parents were chosen and recorded for each of the 127 F_2 plants. The distribution of these characters with one or two exceptions showed little or no evidence of alternative or Mendelian inheritance.

With respect to the individual characters, the extreme variants approached, and in some instance exceeded, those of the parents; but none of the plants possessed any large number of the characters of either maize or teosinte.

The results showed the greatest freedom of recombination. All combinations of characters appeared that might reasonably be expected with so limited a number of individuals. There were many instances of coherence or partial coupling, but there was an almost equal number of instances where characters derived from different parents showed a tendency to combine more frequently than would be expected as the result of chance. In such a complicated series it was found impossible, however, to distinguish primary from secondary correlations.

While there appeared to be no incompatible combinations, there were, on the other hand, no completely independent characters. Every character recorded showed significant correlation with one or more other characters; and these in turn were correlated with still others, with the result that all the characters were interrelated and formed a single group. It is possible, in fact, to arrange all the characters in such a way that they form a single group in which there is no coefficient of correlation lower than ± 0.31 .

The nearest approach to Mendelian inheritance was shown by the arrangement of the spikelets in the pistillate inflorescence (fig. 18, 19, 20). In maize the female spikelets are borne in pairs (double female alicoles); in teosinte the female spikelets are borne singly (single female

alicoles). Dominance of the maize character was complete in the first generation. In the second generation the segregation was not complete, there being many plants with both single and double female alicoles; but the number of individuals in which double female alicoles predominated was approximately three times the number in which there were more single female alicoles.

It was found that the characters of the pistillate inflorescence were subdivided in transmission to a remarkable degree. Thus the maize ear, instead of behaving as a unit, was subdivided into a large number of separately inherited units, such as number of rows, closely crowded seeds, and shortened peduncles, all of which were inherited more or less independently. Number of rows was still further resolved into paired or single spikelets and the number of rows of alicoles in which they were borne.

A surprisingly large number of the plants combined the abundant production of suckers characteristic of the teosinte parent with the sturdy, upright character of maize and resulted in very leafy, compact plants of a type that should prove valuable for forage purposes. (See Pl. 6, A.)

It remains to be seen whether the new combinations can be maintained and made to breed true. The results of previous experiments with maize hybrids would indicate that selection for a few generations will fix any desired combination.

PLATE 1

A.—General view of F_2 plants of teosinte-maize hybrid.

B.— F_2 plants of teosinte-maize hybrid, showing diversity in size and season.





PLATE 2

Teosinte-maize hybrid:

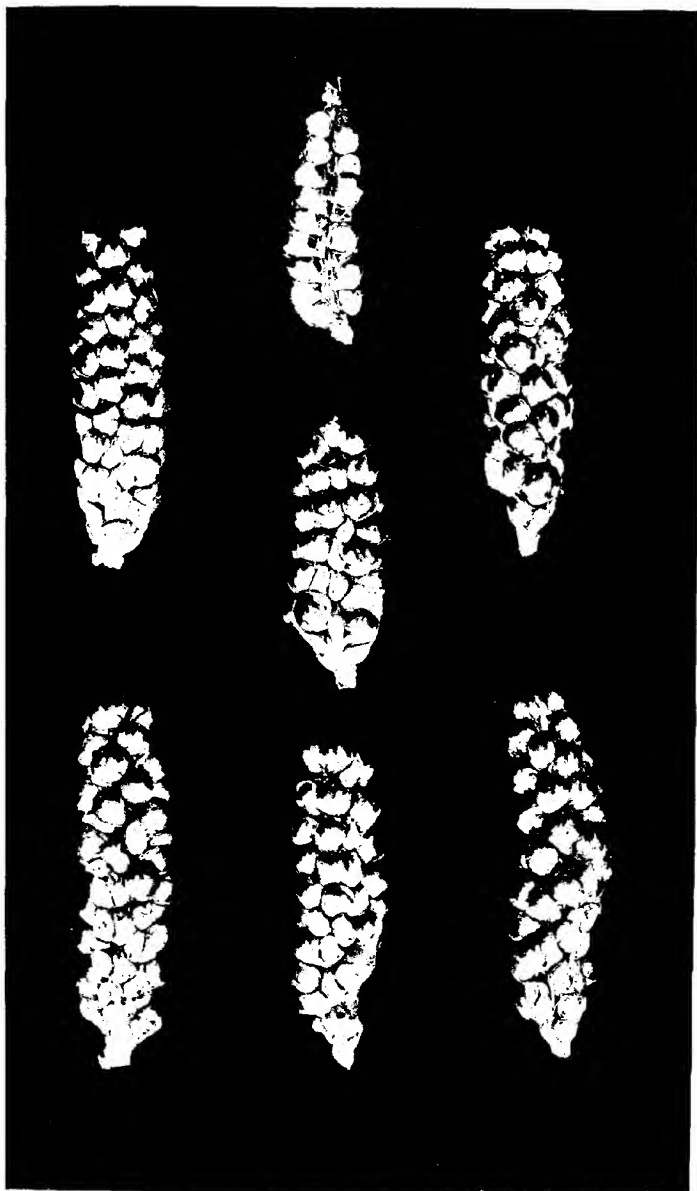
A.—F₂ plant No. 36. This plant bore the most maize-like pistillate inflorescence that appeared in the second generation.

B.—F₂ plant No. 49. The pistillate inflorescences of this plant were among those most nearly resembling teosinte.

PLATE 3

Teosinte-maize hybrid:

Pistillate inflorescence of F_2 plant No. 36, shown in Plate 2, A. Natural size.



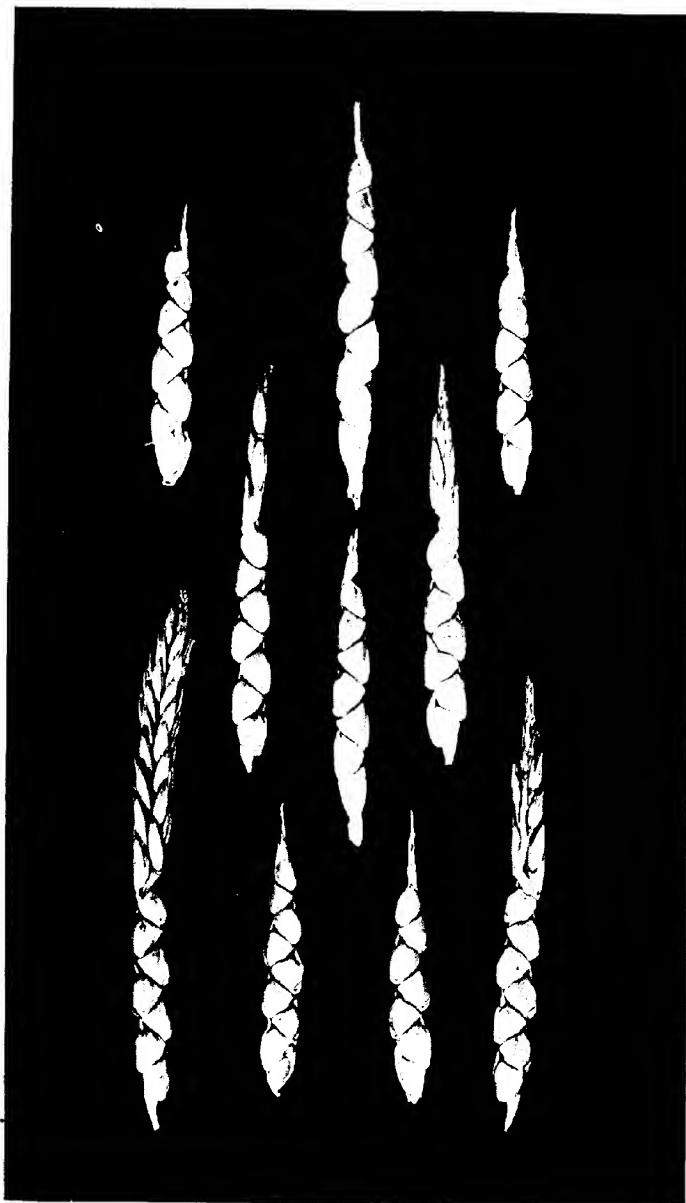


PLATE 4

Pistillate inflorescence of plant No. 49, shown in Plate 2, B.

PLATE 5

Pistillate inflorescences from plant No. 94, illustrating an intermediate type of inflorescence. The arrangement of the alicoles is much like that of teosinte, but 90 per cent of the alicoles are double female.

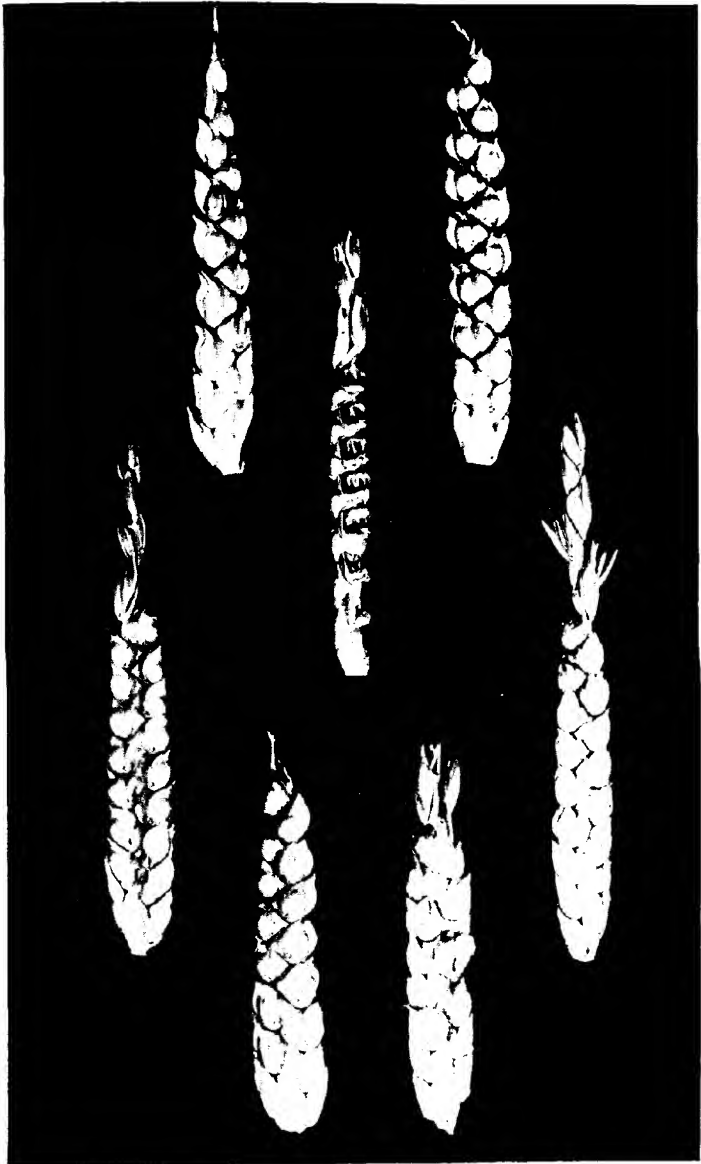




PLATE 6

Teosinte-maize hybrid:

A.—F₂ plant No. 31, showing compact growth characteristic of many of the plants. Although only 14 dcm. high, this plant had 30 leaves on the main culm, nearly equaling teosinte in this respect. The plant resembled maize in having no spikes developed in the axil of the prophyllum.

B.—F₂ plant No. 113, showing stiff, erect leaves. This plant resembled teosinte in being very late in maturing, yet it was among the most maize-like with respect to circumference index.

C.—F₁ plant, grown at Lanham, Md.

PLATE 7

Teosinte-maize hybrid:

Pistillate inflorescences of the F₁ plant shown in Plant 6, C.



BANANA ROOT-BORER

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INTRODUCTION

The existence in Florida of a root-weevil peculiar to the banana was brought to the writer's attention in December, 1917, by the receipt of some specimens from a grower near Larkins, in Dade County, Fla., who advised the writer of serious damage to his banana plants. The insect was determined by Dr. W. Dwight Pierce at Washington, D. C., as the banana root-borer, *Cosmopolites sordidus* Germar, a dangerous banana pest prevalent in almost every section where bananas are grown for commercial purposes. Since this species and all plants infested with it had been declared to be public nuisances in Florida, the State Plant Board at Gainesville, Fla., was immediately notified, and eradication and inspection work was begun. It was during the eradication and inspection work that the writer, cooperating with members of the State Plant Board, was enabled to make a number of observations on the habits of this species; and it was thought well to publish the following data to aid others who may find this pest of the banana in the State of Florida or wherever bananas are grown.

A national quarantine was placed on this species April 1, 1918. This quarantine forbids the importation into the United States from foreign countries where the banana root-borer exists of all species and varieties of banana plants (*Musa* spp.) or portions thereof, except for experimental and scientific purposes.

The spread of the insect from one country to another is probably accomplished by the transportation of infested suckers for planting (11, p. 33-34);² and its spread within any locality most likely follows the killing out of infested stools, after which the adults travel in search of fresh supplies of food plants. Within a locality they could also be spread by the transportation of infested suckers or young plants for propagation.

HISTORY AND DISTRIBUTION

The adult (Pl. 8) was described as *Calandra sordida* by Germar (6) in 1824. The genus *Cosmopolites* was established for this species by Chevrolat (3) in 1885.

E. Fleutiaux (5) recorded it from Madagascar in 1903, stating that it was a serious enemy of the banana on that island. In 1908 C. H. Knowles (9) mentioned carbon disulphid as a means of control in the

¹ Technical descriptions of the stages of the weevil by W. Dwight Pierce.

² Reference is made by number (italic) to "Literature cited," p. 46.

Fiji Islands. In 1912 H. A. Ballou (1, p. 112) reported the species as doing serious damage to bananas in the Lesser Antilles.

During 1914 T. Fletcher (4, p. 342-343, fig. 201) published records of this species from southern India as existing in the regions of Malabar, Caimbatore, Godavari, and Ganjam. In the same year Frank P. Jepson (8), then working with the species in the Fiji Islands, where it is serious, made a mission to Java in quest of the natural enemies of the species and brought into the Fiji Islands some predatory beetles. He was successful in introducing some histerid beetles which were keeping the borers down in Java.

Later in 1916 Ballou (2) reported this insect as widely distributed in the Tropics, it being found in Jamaica, Guadeloupe, Dominica, Martinique, and Trinidad in the West Indies; Brazil in South America; and the Philippines, Fiji, Borneo, Sumatra, India, Queensland, and the Straits Settlements in the East.

Besides the localities cited, Frank P. Jepson (8) in 1914 recorded additional places where it is found: Java, Ceylon, New Guinea, Malacca, Saigon, China, Raratonga, Reunion, Sikhim, North Bengal, Pequ, Tenasserim, Andaman Islands, Sambak, and the Seychelles.

In Florida investigations showed that the infested plantings at Larkins had all been made four years previous to the discovery of the weevils, with plants procured from a nursery in the northern part of Florida which had, in turn, secured the plants from a nursery in southern Florida. In March, 1918, the weevils were found at the nursery in southern Florida, and every effort was made to exterminate them. It may be that many shipments of infested plants were made from this source, and it is very important that every occurrence of this pest be located and eradicated. Since the insect attacks sugar cane also it is not improbable that its presence would seriously interfere in the future with the development of large sugar and sirup industries. It is not known how this insect found its way into Florida, but no doubt it came in with sprouts or young plants introduced for propagation.

HOST PLANTS

According to published records there does not seem to be a great variety of host plants, *Cosmopolites sordidus* apparently having confined itself thus far almost entirely to the banana, attacking all varieties. The borer has been reported, however, as attacking sugar cane. In Fiji, Jepson (7) states that the borer does not appear to display more partiality for one variety of banana than another.

CHARACTER OF THE INJURY

The young suckers attacked by the borers wither and die in a very short space of time. This is due to the feeding and tunneling of the grubs or larvæ between the lateral roots and the bulb (Pl. 11, B), thus cutting off the flow of sap to the plant. The banana plant has no central

tap root, but is supported by numerous lateral roots (Pl. 11, A). An indication that a young plant is infested is the withering and drying of the curled roll of unopened leaves or growing part of the plant. The root, upon examination, is found to be riddled with the larvæ of this insect and when cut open discloses the borer *in situ*. The adult weevils are abundant in the soil about the root and also are found under loose fiber surrounding the base of the stem, at the crown. They also congregate in the cavities caused by the larvæ at the base of the bulb of the banana plant. In the planting at Larkins, Fla., where the infestation was first found, the writer collected 55 adults at the base of one plant and as many as 60 larvæ and pupæ in the bulb. The older plants infested appeared tall and spindling and no doubt succeeded in growing as much as they did by the presence of numerous lateral roots surrounding the bulbs of the plants and because the attacks of the insects had been gradual. Most of the bananas in the planting were old and so riddled by the larvæ as to be readily felled. After feeding thoroughly on a plant the weevils abandon it for another.

TECHNICAL DESCRIPTIONS OF THE SPECIES

The following descriptions by Dr. W. Dwight Pierce are based upon specimens collected at Larkins, Fla., January 19, 1918. The fine drawings accompanying the descriptions were made under Dr. Pierce's supervision by Mr. Harry Bradford and by Dr. Adam Böving.

EGG

The egg is elongate oval, about 2 mm. in length, rounded at one end and more or less pointed at the other, and pure white in color.

LARVA (Pl. 9, B-G)

The larva is characteristically calandrid in form (Pl. 9, B), having the eighth and ninth segments transformed into a sort of pygidial plate bearing very large elongated spiracles on the eighth segment (Pl. 9, F, G). The other abdominal spiracles are all very minute and indistinct. The mesothoracic spiracles are very large. The length of a full-grown larva is at least 13 mm. (The writer has not had a live specimen to measure.) The body is white and the head shield dark reddish brown. The head is quite prominent. The head shield is broadly, elongately emarginate behind (Pl. 9, C). From the center of the emargination on the median line the epicranial suture passes forward, separating the epicranium into two parts (Pl. 9, C). This suture is strongly marked with black on its posterior half and is white from thence forward to the frons, behind which it divides and forms two frontal sutures (Pl. 9, D).

The frons (Pl. 9, D) is subtriangular, emarginate at anterior angles for the antennæ, and emarginate along the epistoma for attachment of the clypeus. The median line is faintly indicated by a dark line in the basal half. The frons has two pairs of large setæ and two pairs of tiny setæ; the three posterior pairs, the last of which is the smallest though the first is also small, form a triangle, the first and last pairs being almost equidistant. The anterior or epistomal pair of setæ are large and are attached opposite the basal angles of the clypeus and some little distance from the antennal fossæ.

The epicranial areas are located on each side of the epicranial suture (Pl. 9, C-E). A pair of light lines depart from the frontal sutures and pass backward almost as far as the light median line of the epicranium, corresponding to adfrontal sutures which sometimes occur in the Rhynchophora. Each lobe of the epicranium bears setæ as follows: One at each terminus of the rudimentary adfrontal suture; a small one opposite the middle of the frontal suture, and a longer one behind this almost equidistant from the epicranial suture; a long hair opposite the basal third of the frontal suture; one opposite the middle of the pleurostoma; one near the hypostomal angle of the mandible; one opposite the basal third of the hypostoma; one on disk behind this; and four tiny ones on the disk near the median basal angle of the lobe.

The antenna is a fleshy 2-jointed appendage located at the lateral angle of the frons (Pl. 9, D); the first joint is broad and short and bears one or more tiny hairs; the second joint is slender, finger-like, but short. The mandibles (Pl. 9, D, E) are very dark brown, bidentate, with median and basal hairs. The clypeus (Pl. 9, D) is attached in front of the frons and is basally marginated with dark brown, but otherwise light in color. It bears four tiny hairs on the epistomal margin. The labrum (Pl. 9, D) is not so broad, is rounded in front, has a row of four setæ in front of the middle, and is marginated with setæ. The maxillæ (Pl. 9, D, E) are elongate, terminated by a 2-jointed palpus and a setose lacinia. They are provided with four setæ, two near palpus and one near base. The stipes labii (Pl. 9, D, E) is triangular cordate, rather acutely angulate at base, bearing 2-jointed palpi at basal angles with a discal pair of setæ and with several pairs of basal setæ.

The body is glabrous except for the usual hairs found on each segment (Pl. 9, B). The prothorax is not divided dorsally on the anterior margin, which corresponds to the praescutum. There are six pairs of setæ, the last of which occurs in the region of the alar lobe. Behind these on the scutal area are four pairs of hairs, the last of which occurs on the alar lobe. The mesothoracic spiracle occurs on a large lobe which causes an emargination of the prothorax and lies very close to the head. It is very elongate with a longitudinal slit. The mesothorax and metathorax dorsally consist of a spindle-shaped praescutum with a single pair of setæ and the scutellum, extending from alar lobe to alar lobe and bearing only two pairs of hairs in the region of the alar lobe. The epipleurum of the mesothorax and metathorax bears a single hair. Each hypopleural lobe bears two setæ. The sternum of the thorax consists of a median area or eusternum and two lateral lobes more or less connected medianly behind the sternum. The median portion is the sternellum and the lateral portions are the parasternal plates. Each thoracic sternum bears one pair of hairs, and each parasternum bears three pairs of hairs.

The first seven abdominal segments are normal, and each bears a very minute spiracle. In a fully matured specimen these segments grow larger to the fourth or fifth segment and then decrease in size. The seventh segment is the smallest of the normal segments. Dorsally each segment is transversely divided into four parts, praescutum, scutum, scutellum, and postscutellum. Each praescutum bears one pair of setæ and each scutellum bears a small lateral pair. Each epipleural lobe bears two pairs of setæ; and each hypopleural lobe is apparently longitudinally divided into two parts, the lower of which bears a single seta. Ventrally, each segment has two transverse lobes, the front one being the eusternum with the presternum depressed in front of it and the parasternum and lobe at each side. The second transverse area is transversely depressed and frontally consists of sternellum and poststernellum. There are no setæ on the sternum of the abdomen. The eighth segment is dorsally greatly modified with a single pair of hairs on the praescutum and a single pair on the scutellar area, and with very elongated spiracles quite prominent (Pl. 9, F, G). Just outside of the spiracles on the epipleural lobe are two strong setæ.

The dorsal face of the eighth segment is declivous (Pl. 9, B); the dorsum of the ninth segment is flattened and bears four pairs of setæ, as shown in the figure (Pl. 9, F). The

dorsum of the ninth segment extends underneath, so that it is apical to the entire tenth segment. The tenth segment is completely ventral and very small. The tip of the abdomen showing the position of the tenth segment is illustrated in Plate 9, G.

PUPA (PL. 10)

Elongate, about 12 mm. long, white. This pupa is characteristically calandrid in the possession of very large thoracic spiracles located on a prominent lobe at the base of the prothorax (Pl. 10, B). The beak is very irregularly margined with numerous transverse depressions (Pl. 10, A). There are four pairs of large setæ and two pairs of tiny setæ on the head and beak. The four larger pairs of setæ are borne on tubercles, one on the head and three on the beak. The two pairs of tiny setæ are located medianly to the two basal pairs on the beak, as shown in the drawing. The prothorax (Pl. 10, C) is rather elongate subquadrate, rounded in front, with basal angles rounded, and bears six pairs of setigerous tubercles, of which the apical pair are the largest. There are two antero-lateral, two postero-lateral, and one antero-median pairs of setæ. The mesothorax has one pair of scutellar setæ. The first six abdominal segments are normal, and each bears three pairs of scutellar setæ. The first six abdominal spiracles are larger and more prominent than the larval spiracles. The seventh and eighth spiracles are minute. The first two ventral segments are very much crowded. The seventh, eighth, ninth, and tenth segments are greatly modified both above and below. Dorsally the seventh segment is elongate, apically it is tuberculate, and it has two pairs of setigerous tubercles, one pair being on the larger apical tubercles. From a lateral view, it is seen that the seventh segment is dorsally the terminal segment, but ventrally it is surpassed by the other segments. In other words, it is laterally emarginate for the reception of the other segments, each of which includes the succeeding segment. The ninth segment is provided with a pair of very long, chitinous processes, corresponding to the cerci, at the side of which are two setigerous tubercles.

Ventrally (Pl. 10, A) the mesothorax is smallest, prothorax next, and metathorax next. The mesosternum is protuberant, the metasternum elongate and flattened. The coxæ are spherical; the femora are setigerous at the apex. The wing pads extend only to about the apex of the fourth abdominal segment.

ADULT (PL. 8)

Length 11 mm.; breadth at base of elytra 4 mm. Head small, spherical; beak separated from head by constriction, swollen in basal third, finely punctate in basal half; moderately curved, slender and cylindrical and smooth in apical half. Scrobes located in basal third beneath the swelling, oval, more approximate behind than in front. Gular suture extending almost entire length of venter of beak and head. Antennæ geniculate, scape almost as long as funicle. Funicle 6-jointed, first joint moniliform, succeeding joints more closely appressed, last joint very closely appressed to club. Club 2-jointed, basal joint occupying two-thirds of the length, shining, with a few minute hairs; apical joint spongy, short, and rounded at apex. Other funicular joints bearing a few tiny hairs. Eyes finely granulate, elongate oval, transversely contiguous beneath, anteriorly margined. Prothorax very long; moderately evenly punctate, with an irregular smooth median line indicated on disk; constricted near apex, apex tubular; narrowest at apex, roundly broadening to about the middle; sides almost parallel from middle. Scutellum small, subquadrate, moderately short, with slight humeral angles. Striæ moderately impressed, punctate. Intervals of irregular width, the first, third, and fifth being slightly wider than the alternate intervals, minutely punctate. Pygidium almost vertical, spongy, pubescent, with setigerous punctures. Undersides more sparsely punctate. Sternum flattened. Procoxæ and mesocoxæ cylindrical, metacoxæ oval, trochanters small, femora laterally

compressed and curved, ventrally inflated at middle, emarginate beyond this and bilobed at apex, thus forming a groove for the tibiae. Tibiae moderately straight, grooved beneath and provided with a row of setae on each side of the groove, apically curved downwards, terminating in a strong hook. Tarsi 4-jointed, first longer than broad, widest at apex, second about as long as broad, third about as long as first but broader at apex, emarginate for reception of fourth. Fourth elongate, curved, subcylindrical, armed with two curved, divergent claws. Intercoxal piece broad, angulate. First two abdominal segments connate at middle. Third and fourth segments about as long as second. Fifth segment longer, turned downward.

LIFE HISTORY

The female beetle having been fertilized enters between a leaf sheath and the stem and selects a spot for the deposition of an egg. The beetle then prepares a small cavity by means of the powerful mandibles located at the tip of the rostrum or beak. After having completed the cavity the beetle reverses its position and with the aid of the ovipositor deposits a single egg in the prepared place (fig. 1). On February 9, 1918, many



FIG. 1.—*Cosmopolites sordidus*: Section of sheath with egg *in situ* in compartment.

eggs were observed which were laid apparently a short time previously in the tissues, usually in the small compartments in the sheaths or stem. A few eggs were even found laid loosely in the slightly decayed leaf sheaths close to the healthy fleshy banana bulb, from which place they entered the bulb. The eggs, for the most part, are deposited singly in the sheaths near the crown at the surface of the soil. On hatching, the egg does not completely collapse. The larvæ eat their way in all directions in the bulb, and one can easily trace a channel as it gradually grows wider, terminating in a pouch near the outer surface in which the larva pupates on reaching maturity. The records for oviposition, hatching, and pupation are given in Table I.

TABLE I.—Egg and larval records of *Cosmopolites sordidus*, 1918

Egg No.	Egg deposited.	Egg hatched.	Larva pupated.
1.....	Feb. 10	Feb. 15	Mar. 2
2.....	do.	do.	Mar. 3
3.....	do.	do.	Do.
4.....	do.	Feb. 16	Mar. 2
5.....	do.	do.	Mar. 3
6.....	do.	Feb. 17	Mar. 4
7.....	do.	do.	Mar. 3
8.....	do.	do.	Mar. 6
9.....	do.	do.	Mar. 5
10.....	do.	do.	Mar. 6

From a few experiments the egg period was found to last from 5 to 7 days. From the character of the channels of the grubs it is the opinion of the writer that the eggs are deposited in the outer sheaths or between the outer sheath and the stem, the grubs working their way into the body of the bulb or trunk. The work of the larvæ is particularly destructive, since they girdle the plant in the immediate vicinity of the lateral roots put out from the bulb of the plant (Pl. 11, A), thus cutting off the passage of the sap. The larvæ not only work frequently in this region just described but may be found tunneling into the main trunk as far as the heartwood. The larvæ usually work below ground, but in a number of instances the writer has found them in the trunk as high as 2 feet above ground. The larval stage was found to last over a period of from 15 to 20 days. Due to the scarcity of material and to the fact that all infestations were gradually destroyed and cleaned up, the writer was unable to make further records on the seasonal habits of the species.

The larvæ upon attaining maturity construct an oval space at the end of the burrows, usually well toward the outer layers, where the larval head is cast, and where the larva pupates. The pupæ are naked. Jepson found in Fiji that a period of from 5 to 8 days from the time of pupation elapses before the emergence of the adult. The adults bear wings and are very sluggish. When disturbed they will "play 'possum" for a considerable length of time. The adults are gregarious and were found in clusters in cavities and depressions in the outer sheaths of the banana close to the surface of the ground and also below the surface. The length of life of the adult is not known. The writer has kept them in captivity without food for two months. Jepson in Fiji has kept the beetles in captivity about 14 weeks without food, and in the state of nature they undoubtedly will live longer. In all probability the banana root-borer continues to breed all the year round, provided that the food supply is plentiful. The beetles are nocturnal, only coming up from the soil at night for their activities above ground.

CONTROL

Since bananas are grown year after year on the same land and are produced from suckers springing from the parent plant, a plantation usually forms a breeding ground and nursery for these insects. The borer's mode of life renders it a difficult pest to control, as Knowles and Jepson (20) noted in Fiji. The egg, larval, and pupal periods are passed in or on the bulb of the banana or plantain. The adults apparently do not move far from the place where they have lived and developed so long as suitable food is available to attract the egg-laying females. In Java *Cosmopolites sordidus* is preyed upon and kept down by the larvæ of a histrid beetle and by those of some beetle of the family of Hydrophilidae. Jepson introduced these species into Fiji, where the banana root-borer is a serious

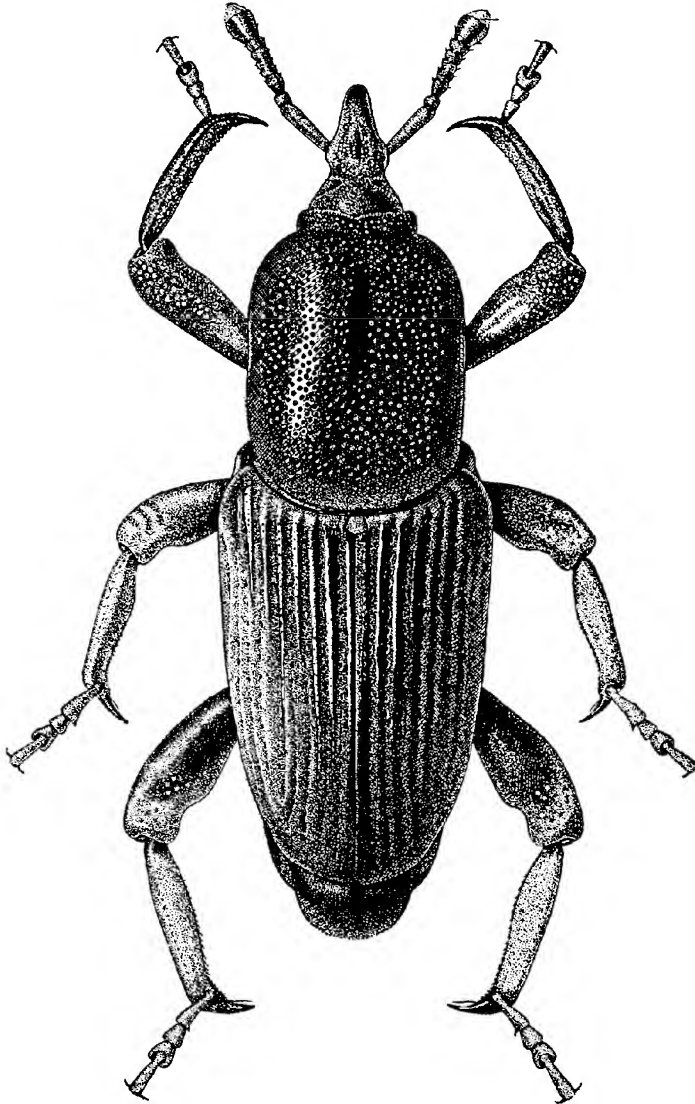
pest. Where banana plants are found infested in Florida and elsewhere in the States they should be destroyed immediately, and traps should be laid by using strips of healthy banana trunks. In Florida strips of banana plants proved more successful as a trap than did young plants on an infested piece of ground. As the beetles congregate under and about these strips they should be burned and the process repeated until the beetles are eradicated. It is very important that the traps be renewed, since the beetles are capable of living a considerable time without food.

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PLATE 8

Banana root-borer (*Cosmopolites sordidus*): Adult.



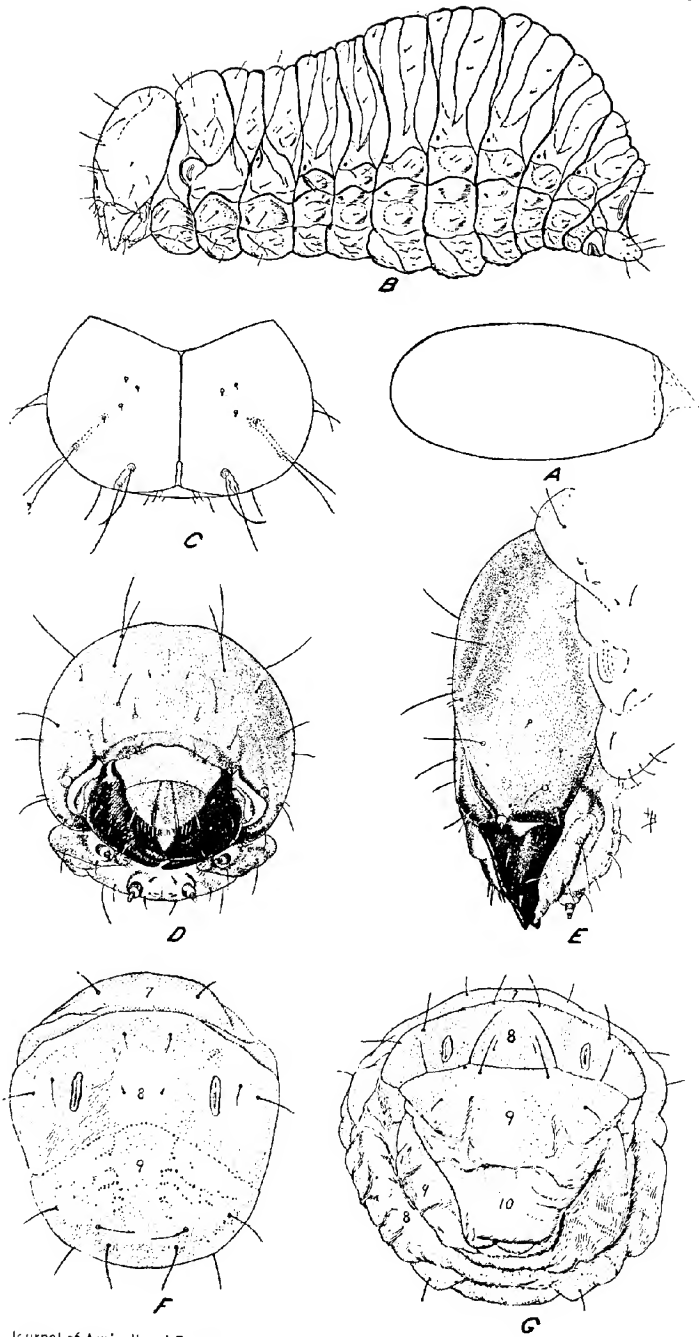


PLATE 9

Egg and larva of banana root-borer:

- A.—Egg.
- B.—Larva, side view.
- C.—Head of larva, dorsal view.
- D.—Head of larva, face view.
- E.—Head of larva, side view.
- F.—Dorsal view of seventh, eighth, and ninth abdominal segments.
- G.—Posterior view of segments 7 to 10.

PLATE 10

Pupa and adult of banana root-borer:

- A.—Ventral view of pupa.
- B.—Lateral view of head and thorax of pupa.
- C.—Dorsal view of pupa.

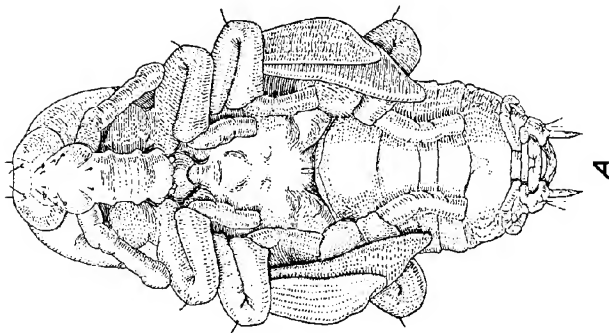
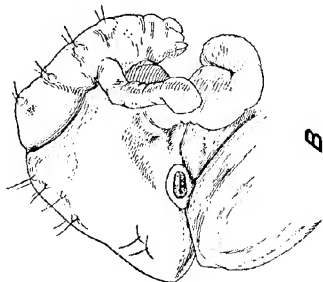
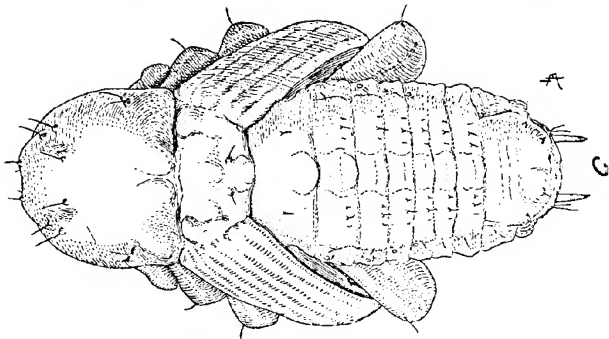




PLATE 11

A.—Young healthy banana plant bulb with lateral roots.

B.—Young banana plant cut into, showing work of the larvæ of the banana root-borer. Illustration shows how lateral roots become severed by grubs working near roots.

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